U.S. Department of Transportation

Federal Aviation Administration

Advisory Circular

AC 90-94A

DRAFT

GUIDELINES FOR OPERATORS USING GLOBAL POSITIONING SYSTEM EQUIPMENT FOR IFR EN ROUTE AND TERMINAL OPERATIONS AND FOR NONPRECISION INSTRUMENT APPROACHES IN THE U.S. NATIONAL AIRSPACE SYSTEM

1. PURPOSE. This advisory circular (AC) contains guidance for pilots to use Global Positioning System (GPS) equipment during instrument flight rules (IFR) navigation. It includes operating en route, in the terminal environment, during GPS nonprecision instrument approach procedures in the U.S. National Airspace System (NAS), and in oceanic areas. This document amends AC 90-94 by adding primary means GPS oceanic/remote operations. This document is advisory only and not mandatory.

2. CANCELLATION. AC 90-94, Guidelines for using Global Positioning System Equipment for IFR En Route and Terminal Operations and for Nonprecision Instrument Approaches in the U.S. National Airspace System, dated December 14, 1994, is canceled.

3. RELATED READING MATERIAL. The guidelines within this AC complement the following documents:

a. RTCA No. RTCA/DO-200, November 18, 1988, "Preparation, Verification and Distribution of User-Selectable Navigation Data Bases."

b. RTCA No. RTCA/DO-208, July 1991, "Minimum Operational Performance Standards for Airborne Supplemental Navigation Equipment Using Global Positioning System (GPS)."

c. Technical Standard Order (TSO)-C129, December 10, 1992, "Airborne Supplemental Navigation Equipment Using the Global Positioning System (GPS)."

d. FAA AC 20-138, May 25, 1994, "Airworthiness Approval of Global Positioning System (GPS) Navigation Equipment for Use as a VFR and IFR Supplemental Navigation System."

4. BACKGROUND. The U. S. Department of Defense (DOD) originally developed and deployed GPS as a space-based positioning, velocity, and time system for the military. The GPS is managed by the Interagency GPS Executive Board and operated by the DOD. The GPS system permits earth-centered coordinates to be determined and provides aircraft position referenced to the World Geodetic System of 1984 (WGS-84). Navigational values, such as distance and bearing to a waypoint and ground speed, are computed from the aircraft's current position (latitude and longitude) and the location of the next waypoint. Course guidance is provided as a linear deviation from the desired track of a Great Circle route between defined waypoints.

a. The rapid development of this technology and the establishment of TSO-C129, "Airborne Supplemental Navigation Equipment Using the Global Positioning System (GPS)", has made possible the first civil aviation use of GPS in IFR procedures.

b. TSO-C129 (as amended) sets the minimum performance standards that GPS airborne supplemental area navigation (RNAV) equipment must meet to operate in the U.S. NAS during en route, terminal, and nonprecision approach procedures.

> **Note: Equipment approved to TSO-C115a does not meet the requirements of TSO-C129.**

c. The DOD declared initial operational capability (IOC) of the U.S. GPS on December 8, 1993. The FAA issued a notice to airmen (NOTAM) on February 17, 1994, declaring GPS operational for certain civil IFR applications. A NOTAM, issued March 3, 1994, specified the applications.

d. This AC provides the performance requirements that GPS airborne RNAV equipment must meet to be authorized for use as a primary means of Class II navigation for oceanic/remote operations.

> **Note: Aircraft which are equipped with another approved long-range navigation system, such as INS, need not apply for GPS primary means approval; they may utilize GPS under supplemental IFR approval.**

5. DEFINITIONS. This AC contains several technical terms which may not be familiar to the new GPS user. A list of definitions can be found in the Glossary, Appendix 1.

6. COMMENTS INVITED. Comments regarding this publication should be directed to the following address:

Federal Aviation Administration
Technical Programs Division, AFS-400
Flight Standards Service
800 Independence Avenue, S.W.
Washington, D.C. 20591

Comments may not require a direct acknowledgment to the commentor; however, they will be considered in the development of upcoming revisions to AC's or other related technical material.

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APPENDICES

SECTION 1. GENERAL.

1. BACKGROUND. GLOBAL POSITIONING SYSTEM (GPS). This AC provides guidance and procedures for the use of satellite navigation in the U.S. National Airspace System (NAS), for oceanic navigation, and where applicable, satellite navigation outside the NAS. Satellite navigation systems provide global navigation that meet civil aviation requirements for use in aircraft navigation. Developments in satellite technology and its use for aircraft navigation are such that it may be expected that new satellite navigation systems will evolve in the future, each with its own unique characteristics. The International Civil Aviation Organization (ICAO) has adopted "Global Navigation Satellite System (GNSS)" as an umbrella term to identify any satellite navigation system where the user performs onboard position determination from satellite information. Currently there are only two GNSS systems that are recognized by the International Frequency Registration Board (IFRB): the Global Positioning System (GPS) developed by the United States and the Global Orbiting Navigation Satellite System (GLONASS) now under development by the Federation of Russia.

2. GPS ARCHITECTURE. GPS consists of three distinct functional elements: the space element, the ground-based control element, and the aircraft-based user element.

a. The space element consists of 24 Navstar satellites. This group of satellites is called a constellation. The satellites are in six orbital planes (with four in each plane) located approximately 11,000 miles above the earth. At least five satellites are in view at all times. The GPS constellation broadcasts a pseudo-random code timing signal and data message that airborne GPS equipment processes to obtain satellite position and status data. By knowing the precise location of each satellite and precisely matching timing with the atomic clocks on the satellites, the airborne receiver can accurately measure the time each signal takes to arrive at the receiver and, therefore, determine aircraft position.

b. The ground-based control element consists of a network of GPS monitoring and control stations that ensure the accuracy of satellite positions and their clocks. In its present form, the ground-based system consists of five monitoring stations, three ground antennas, and a master control station.

c. The aircraft-based user element consists of special GPS antennas and satellite receiver-processors (with a database) onboard the aircraft that provide positioning, velocity, and precise timing information to the pilot.

d. A minimum of three satellites must be in view to determine lateral guidance (2D position). Four satellites must be in view to provide both lateral and vertical guidance (3D position).

3. SYSTEM DESCRIPTION. GPS is a United States satellite-based radio navigational, positioning, and time transfer system. The system provides highly accurate position and velocity information and precise time on a continuous global basis to an unlimited number of properly-equipped users. The system is unaffected by weather and provides a worldwide common grid reference system based on the earth-fixed coordinate system. For its earth model, GPS uses the World Geodetic System of 1984 (WGS-84) datum.

a. GPS provides two levels of service: Standard Positioning Service (SPS) and Precise Positioning Service (PPS). SPS provides, to all users, horizontal positioning accuracy of 100 meters, or less, with a probability of 95 percent and 300 meters with a probability of 99.99 percent. PPS is more accurate than SPS; however, the use of PPS is limited to authorized U.S. and allied military, federal government, and certain designated civil users who satisfy specific U.S. requirements.

b. GPS operation is based on the concept of ranging and triangulation from a group of satellites in space which act as precise reference points. A GPS receiver measures distance from a satellite using the travel time of a radio signal. Each satellite transmits a specific code, called a course acquisition (CA) code, which contains information on the satellite's position, the GPS system time, and the health and accuracy of the transmitted data. Knowing the speed at which the signal traveled (approximately 186,000 miles per second) and the exact broadcast time, the distance traveled by the signal can be computed from the arrival time.

c. The GPS receiver matches each satellite's CA code with an identical copy of the code contained in the receiver's data base. By shifting its copy of the satellite's code in a matching process, and by comparing this shift with its internal clock, the receiver can calculate how long it took the signal to travel from the satellite to the receiver. The distance derived from this method of computing distance is called a pseudo-range because it is not a direct measurement of distance, but a measurement based on time. Pseudo-range is subject to several error sources, for example, ionospheric and tropospheric delays and multipath errors.

d. In addition to knowing the distance to a satellite, a receiver needs to know the satellite's exact position in space; this is referred to as its "ephemeris." Each satellite transmits information about its exact orbital location. The GPS receiver uses this information to precisely establish the position of the satellite.

e. Using the calculated pseudo-range and position information supplied by the satellite, the GPS receiver mathematically determines its position by triangulation. The GPS receiver requires at least four satellites to yield a three-dimensional *position* (latitude, longitude, and altitude) and *time* solution. The GPS receiver computes navigational values, such as distance and bearing to a waypoint or determining ground speed, by using the aircraft's known latitude/longitude and referencing these to a data base built into the receiver.

f. The GPS constellation of 24 satellites is designed so that a minimum of five are always observable by a user anywhere on earth. The receiver uses data from a minimum of four satellites above the mask angle (the lowest angle above the horizon at which it can use a satellite). The GPS receiver verifies the integrity (usability) of the signals received from the GPS constellation through receiver autonomous integrity monitoring (RAIM) to determine if a satellite is providing corrupted information. At least one satellite, in addition to those required for navigation, must be in view for the receiver to perform the RAIM function; thus, RAIM needs a minimum of five satellites in view, or four satellites and a barometric altimeter (baro-aiding) to detect an integrity anomaly. Baro-aiding is a method of augmenting the GPS integrity solution by using a nonsatellite input source. To ensure that baro-aiding is available, the current altimeter setting must be entered into the receiver as described in the operating manual.

g. RAIM messages vary somewhat between receivers; however, generally there are two types. One type indicates that there are not sufficient satellites available to provide RAIM and another type indicates that the RAIM has detected a potential error that exceeds the limit for the current phase of flight. **Without RAIM capability, the pilot has no assurance of the accuracy of the GPS position.**

h. Some satellite receivers are capable of isolating a corrupt satellite signal and removing it from the navigation solution using a process called Fault Detection and Exclusion (FDE). FDE requires six satellites in view or five satellites with baro-aiding to isolate the bad satellite signal and continue to provide a valid navigation signal.

i. The Department of Defense declared initial operational capability (IOC) of the U.S. GPS on December 8, 1993. Properly certified GPS equipment may be used for IFR navigation in domestic en route and terminal operations, and GPS instrument approach procedures (IAP's). U.S. civil operators may use properly certified GPS equipment as a primary means of navigation in oceanic airspace and certain remote areas. These approvals permit the use of GPS in a manner that is consistent with current navigation requirements as well as approved air carrier operations specifications.

j. Operational Requirements.

(1) GPS Instrument Flight Rules (IFR) operations for en route (oceanic and domestic), terminal, and nonprecision approach phases of flight can be conducted when GPS avionics approved for IFR are installed in the aircraft as follows:

(2) Authorization to conduct any GPS operation under IFR requires that:

(a) GPS navigation equipment used must be approved in accordance with the requirements specified in TSO-C129, or equivalent, and the installation must be done in accordance with AC 20-138 or AC 20-130A, or equivalent. Equipment approved in accordance with TSO-C115a does not meet the requirements of TSO-C129.

(b) Aircraft using GPS navigation equipment under IFR must be equipped with an approved and operational alternate means of navigation appropriate to the flight. Active monitoring of alternative navigation equipment is not required if the GPS receiver uses RAIM for integrity monitoring. Active monitoring of an alternate means of navigation *is* required when the RAIM capability of the GPS equipment is lost.

(c) Procedures must be established for use in the event that the loss of RAIM capability is predicted to occur. In situations where this is encountered, the flight must rely on other approved equipment, delay departure, or cancel the flight.

(d) The GPS operation must be conducted in accordance with the FAA-approved aircraft flight manual (AFM) or flight manual supplement. Flight crew members must be thoroughly familiar with the particular GPS equipment installed in the aircraft, the receiver operation manual, and the AFM or flight manual supplement.

Note: Unlike ILS and VOR, the basic operation, receiver presentation to the pilot, and some capabilities of the equipment can vary greatly Due to these differences, operation of different brands, or even models of the same brand, of GPS receiver under IFR should not be attempted without thorough study of the operation of that particular receiver and installation. Many receivers have a built-in simulator mode which will allow the pilot to become familiar with operation prior to attempting operation in the aircraft. Using the equipment in flight under VFR conditions prior to attempting IFR operation will allow further familiarization.

(e) Aircraft navigating by IFR approved GPS are considered to be RNAV aircraft and have special equipment suffixes. File the appropriate equipment suffix on the air traffic control (ATC) flight plan. If GPS avionics become inoperative, the pilot should advise ATC.

(f) Prior to any GPS IFR operation, the pilot must review appropriate NOTAM's and aeronautical information. (See GPS NOTAM's/Aeronautical Information.)

(g) Air carrier and commercial operators must meet the appropriate provisions of their approved operations specifications.

4. GPS EQUIPMENT CLASSES: GPS equipment is categorized into three equipment classes: Class A, Class B and Class C. Each class of equipment is broken down into subclasses (e.g. A1, A2) according to the operational capabilities of each subclass. Authorization to fly approaches under IFR using GPS avionics systems requires that pilot use GPS avionics certified in accordance with TSO-C129, or equivalent. All approach procedures to be flown must be retrievable from the current airborne navigation data base supplied by the TSO-C129 equipment manufacturer or other FAA approved source. A description of each class follows:

a. Class A1 and A2. Equipment incorporating both the GPS sensor and navigating capability. This equipment incorporates Receiver Autonomous Integrity Monitoring (RAIM). Class A1 equipment includes en route, terminal, and GPS nonprecision approach (except localizer, localizer directional aid (LDA), and simplified directional facility (SDF)) navigation capability. Class A2 equipment includes en route and terminal navigation capability only.

b. Class B1, B2, B3, and B4. Equipment consisting of a GPS sensor that provides data to an integrated navigation system (i.e., flight management systems, multi-sensor navigation systems). Class B1 equipment includes RAIM and provides en route, terminal, and GPS nonprecision approach (except localizer, LDA, and SDF) capability. Class B2 equipment includes RAIM and provides en route and terminal capability only. Class B3 equipment requires the integrated navigation system to provide a level of GPS integrity equivalent to RAIM and provides en route, terminal, and GPS non-precision approach (except localizer, LDA, and SDF) capability. Class B4 equipment requires the integrated navigation system to provide a level of GPS integrity equivalent to RAIM and provides en route and terminal capability only.

c. Class C1, C2, C3 and C4. Equipment consisting of a GPS sensor that provides data to an integrated navigation system (i.e., flight management system, multi-sensor navigation systems) which provides enhanced guidance to an autopilot or flight director in order to reduce flight technical errors. Class C1 equipment includes RAIM and provides en route, terminal, and nonprecision approach (except localizer, LDA, and SDF) capability. Class C2 equipment includes RAIM and provides en route and terminal capability only. Class C3 equipment requires the integrated navigation system to provide a level of GPS integrity equivalent to RAIM and provides en route, terminal, and nonprecision approach (except localizer, LDA, and SDF) capability. Class C4 equipment requires the integrated navigation system to provide a level of GPS integrity equivalent to RAIM and provides en route and terminal capability only.

d. Operational Capabilities. The operational capabilities of the equipment classes and subclasses are outlined in Figure 1.

GPS IFR EQUIPMENT CLASSES/SUBCLASSES (TSO-C129)						
Equipment Class	RAIM	Integrated Navigation System to provide RAIM Equivalent	Oceanic	En Route	Terminal	Non-Precision Approach Capable
Class A — GPS sensor and navigation capability.						
A1	yes		yes	yes	yes	yes
A2	yes		yes	yes	Yes	no
Class B — GPS sensor data to an integrated navigation system (i.e., FMS, multi-sensor navigation systems)						
B1	yes		yes	yes	yes	yes
B2	yes		yes	yes	yes	no
B3		yes	yes	yes	yes	yes
B4		yes	yes	yes	yes	no
Class C — GPS sensor data to an integrated nav system (as in Class B) which provide enhanced guidance to an autopilot, or flight director, to reduce flight technical errors enhanced guidance to an autopilot, or flight director, to reduce flight technical errors. Limited to Title 14 of Code of Federal Regulations (14 CFR) part 121 or equivalent.						
C1	yes		yes	yes	yes	yes
C2	yes		yes	yes	yes	no
C3		yes	yes	yes	yes	yes
C4		yes	yes	yes	yes	no

Figure 1. GPS Equipment Classes

5. GPS SYSTEM ACCURACY/ERRORS. GPS equipment determines its position by precise measurement of the distance from selected satellites in the system, and the satellites' known location. Accuracy measurements are affected by satellite geometry (which multiplies the effect of other errors in the system), slight inaccuracies in the satellite clocks, receiver processing, signal reflections, and predictions of current satellite position that are transmitted to the receiver in the satellite data message. The accuracy of GPS position data can be affected by equipment and the satellite geometry being received. Many of these errors can be reduced or eliminated with mathematics and sophisticated modeling provided by the airborne receiver.

> **NOTE: Selective Availability (SA) is the means which the DOD uses to artificially create errors in the signals from the satellites. This feature is designed to deny a potential enemy the use of precise GPS positioning data. This is the largest source of error in the GPS system. When SA is active however, the DOD guarantees that the horizontal position accuracy will not be degraded beyond 100 meters (328 feet) 95 percent of the time and 300 meters (984 feet) 99.99 percent of the time**.

SECTION 2. GPS IN THE NATIONAL AIRSPACE SYSTEM (NAS).

1. GENERAL. GPS IFR operations for Instrument Departure Procedures (DP's), formerly Standard Instrument Departures (SID's), en route navigation, Standard Terminal Arrival Routes (STAR's) and terminal Standard Instrument Approach Procedures (SIAP's) should be conducted in the same manner as conventional RNAV operations.

a. For domestic en route GPS flight operations, the aircraft must have navigational equipment installed and operational that can receive all the ground-based facilities appropriate for the route to the destination airport and any required alternate airport. The ground-based facilities necessary for these routes must also be operational. These ground-based systems do not have to be actively used to monitor the GPS avionics unless RAIM failure occurs. Within the contiguous United States, Alaska, Hawaii, and surrounding coastal waters, this requirement may be met with an operational independent VOR, NDB, TACAN, or LORAN-C receiver in addition to the GPS system for IFR operation.

> **Note: GPS may not be approved for IFR use in other countries. Pilots should ensure that GPS is authorized by the appropriate sovereign state prior to its use.**

b. GPS domestic terminal IFR operations can be conducted as soon as the proper avionics systems are installed, provided all general requirements are met. Ground-based facilities necessary for these terminal operations may or *may not* be required depending on the type of GPS approach that is flown, as discussed below:

2. GPS "STAND ALONE" APPROACHES. "Stand alone" GPS nonprecision approaches are those which are not overlaid on an existing approach. The first stand alone GPS approaches were published on July 21, 1994. The airborne-based equipment and ground-based NAVAID requirements are the same for GPS stand alone approaches as for the overlay approaches containing "GPS" in the title, as described above. The "stand alone" approach consists of a sequence of waypoints defining the point to point track to be flown and will be contained in the GPS database as a series of waypoints. Typically, each approach will include the initial approach waypoint, intermediate waypoint, final approach waypoint, missed approach waypoint, missed approach turning waypoint, and missed approach holding waypoint. All waypoints, except a missed approach waypoint, will be coded with a five-letter alpha character name. Missed approach waypoints will be assigned a database identifier. The sequence of waypoints appearing in the display should be identical to the waypoint sequence appearing on an associated GPS approach chart. Stand Alone Copter GPS approaches, including the missed approach, should be flown at 70 Knots or less, since the route width, turn radius and descent rates are all based on this speed.

a. Overlay and Stand Alone Approaches. There will continue to be a mixture of nonprecision GPS overlay and GPS stand alone approaches in the U.S. NAS for some time. Most nonprecision instrument approach procedures in the U.S. (except localizer, LDA, and SDF) are available under the overlay program when there is not a stand alone GPS approach to that runway. The FAA will continue to develop and authorize stand alone GPS approaches. Examples of Overlay and Stand Alone Approaches are contained in Appendix 3.

b. Waypoints. GPS approaches make use of both “fly-over” and “fly-by” waypoints. Fly-by waypoints are used when an aircraft should begin a turn to the next course prior to reaching the waypoint separating the two route segments. This is known as turn anticipation and is compensated for in the airspace and terrain clearances.

(1) Approach waypoints, except for the missed approach waypoint (MAWP) and the missed approach holding waypoint (MAHWP), are normally fly-by waypoints. Fly-over waypoints are used when the aircraft must fly over the point prior to starting a turn. Approach charts depict fly-over waypoints as a circled waypoint symbol. Overlay approach charts and some early stand alone GPS approach charts may not reflect this convention.

(2) On overlay approaches (titled “or GPS”), if no pronounceable five character name is published for an approach waypoint or fix, it may be given an ARINC data base identifier consisting of letters and numbers. These points will appear in the list of waypoints in the approach procedure data base, but may not appear on the approach chart. Procedures without a final approach fix (FAF), for instance, have a sensor final approach waypoint (FAWP) added to the data base at least 4 NM prior to the MAWP to allow the receiver to transition to the approach mode. Some approaches also contain an additional waypoint in the holding pattern when the MAWP and MAHWP are colocated. Arc and radial approaches have an additional waypoint that is used for turn anticipation computation where the arc joins the final approach course. These coded names will not be used by ATC.

(3) Unnamed waypoints in the data base will be uniquely identified for each airport but may be repeated for another airport (e.g., RW36 will be used at each airport with a runway 36 but will be at the same location for all approaches at a given airport).

(4) The runway threshold waypoint is also used as the center of the minimum sector altitude (MSA) on most GPS approaches. MAWP’s not located at the threshold will have a five letter identifier or be designated as Mxx instead of RWxx.

3. APPROACH OVERLAY PROGRAM. To accelerate the availability of instrument approach procedures to be flown using certified GPS equipment, the FAA developed the GPS Approach Overlay Program. This program allows pilots to use GPS equipment to fly existing VOR, VOR/DME, NDB, NDB/DME, TACAN, and RNAV nonprecision instrument approach procedures. The approach overlay program is limited to U.S. airspace. GPS instrument approach operations outside the U.S. must be authorized by the appropriate sovereign state.

a. The purpose of the approach overlay program is to permit pilots to transition from ground-based to satellite-based navigation technology for instrument approaches. GPS equipment may be used to fly all nonprecision instrument approach procedures that are retrieved from a database, except localizer, localizer directional aid (LDA), and simplified directional facility (SDF) approach procedures.

b. Any required alternate airport must have an approved instrument approach procedure, other than GPS or LORAN-C, which is anticipated to be operational at the estimated time of arrival. The approach overlay program permits the use of GPS equipment for certain non-precision approaches according to two very specific sets of conditions that each have specific provisions and limitations. The appropriate condition is indicated by the inclusion (or not) of "GPS" in the title of the approach procedure:

(1) "GPS" *not* included in the title of the procedure: permitted with ground-based NAVAID(s) Operational.

(a) This type of overlay GPS approach was approved in 1994 when the FAA declared the system suitable for civil operations. GPS avionics can be used as the IFR flight guidance system for an approach without actively monitoring the ground-based NAVAID(s) which defines the approach. However, the ground-based NAVAID(s) *must* be operational. In addition, the related avionics must be installed and operational but need not be turned on during the approach (monitoring backup navigation is always recommended when available).

(b) Approaches must be requested and approved using the published title of the existing approach procedure, such as "VOR RWY 24." The avionics need not be operating during the approach if RAIM is providing integrity.

(2) "GPS" *is* included in the title of the procedure: permitted with ground-based NAVAID(s) not required:

(a) This type of overlay GPS approach was approved when the first instrument approach procedures were published to include "or GPS" in the title of the published approach procedure. Instrument approach procedures were retailed "or GPS" (e.g., VOR or GPS RWY 24). Ground-based NAVAID's are not required to be operational and associated aircraft avionics need not be installed, operational, turned on or monitored. (Monitoring of the underlying approach is suggested when equipment is available and functional).

(b) GPS approaches are requested and approved using the GPS title, such as "GPS RWY 24." However, for GPS systems that do not use RAIM for integrity, the ground-based NAVAID(s) and the airborne avionics that provide the equivalent integrity must be installed and operating during the approach.

NOTE: Alternate Airport requirements. In each of the two above conditions, any time an alternate airport is required, the alternate airport must have an approved instrument approach procedure, other

<u>than GPS</u>, which is anticipated to be operational and available at the estimated time of arrival and which the aircraft is equipped to fly.

4. GPS STANDARD INSTRUMENT APPROACH PROCEDURE (SIAP) DESIGN CONCEPTS (TAA).

a. The objective of the Terminal Arrival Area (TAA) procedure design is to provide a new transition method for arriving aircraft equipped with FMS and/or GPS navigational equipment. The TAA contains within it a “T” structure that normally provides a NoPT for aircraft using the approach. The TAA provides the pilot and air traffic controller with a very efficient method for routing traffic from en route to terminal structure.

b. The basic “T” that is contained in the TAA normally aligns the procedure on runway centerline, with the missed approach point (MAP) located at the threshold, the final approach fix (FAF) 5 NM from the threshold, and the intermediate fix (IF) 5 NM from the FAF. Two initial approach fixes (IAF’s) are located 3 to 6 miles from the center IF (IAF). All of these waypoint fixes will be named with a five character pronounceable name. The length of the initial segment varies with the category of aircraft using the procedure or descent gradient requirements. The minimum length of an initial segment designed for Category A aircraft is 3 NM. The minimum length for an initial segment designed for Category E aircraft is 6 NM. These initial segments are constructed perpendicular (90°) to the intermediate segment. There is a holding pattern at the IF (IAF) for course reversal requirements. For example, some pilots may desire to execute a hold “in lieu” of procedure turn (PT) to meet a descent gradient requirement. The missed approach segment is ideally aligned with the final approach course and terminates in a direct entry into a holding pattern. (See Figure 2-1.) Certain conditions, such as terrain, may require modification of the leg lengths and/or angles and a different MAP routing. (See Figure 2-2.)

Basic "T" Design

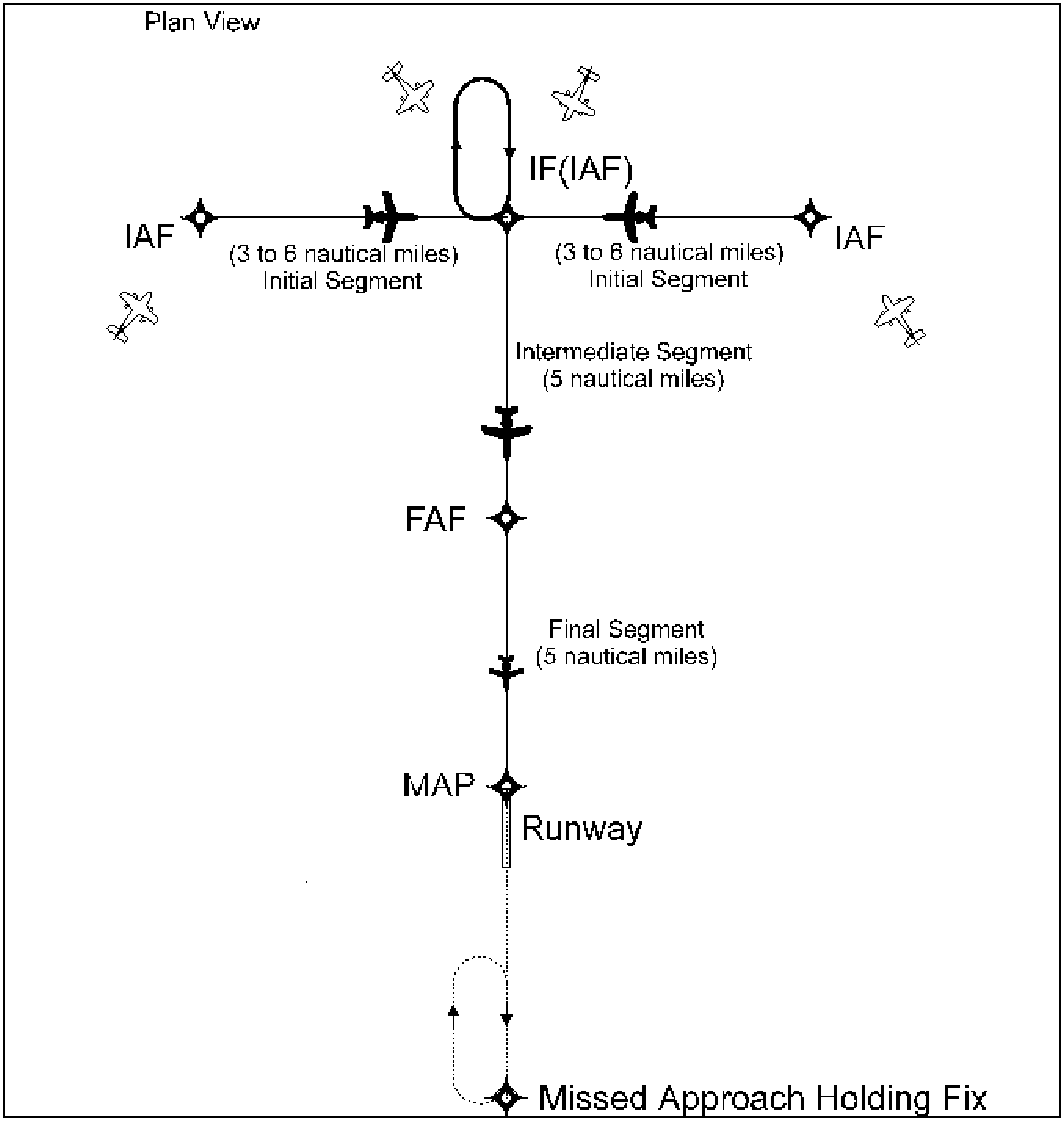


Figure 2.1

Basic “T” Design

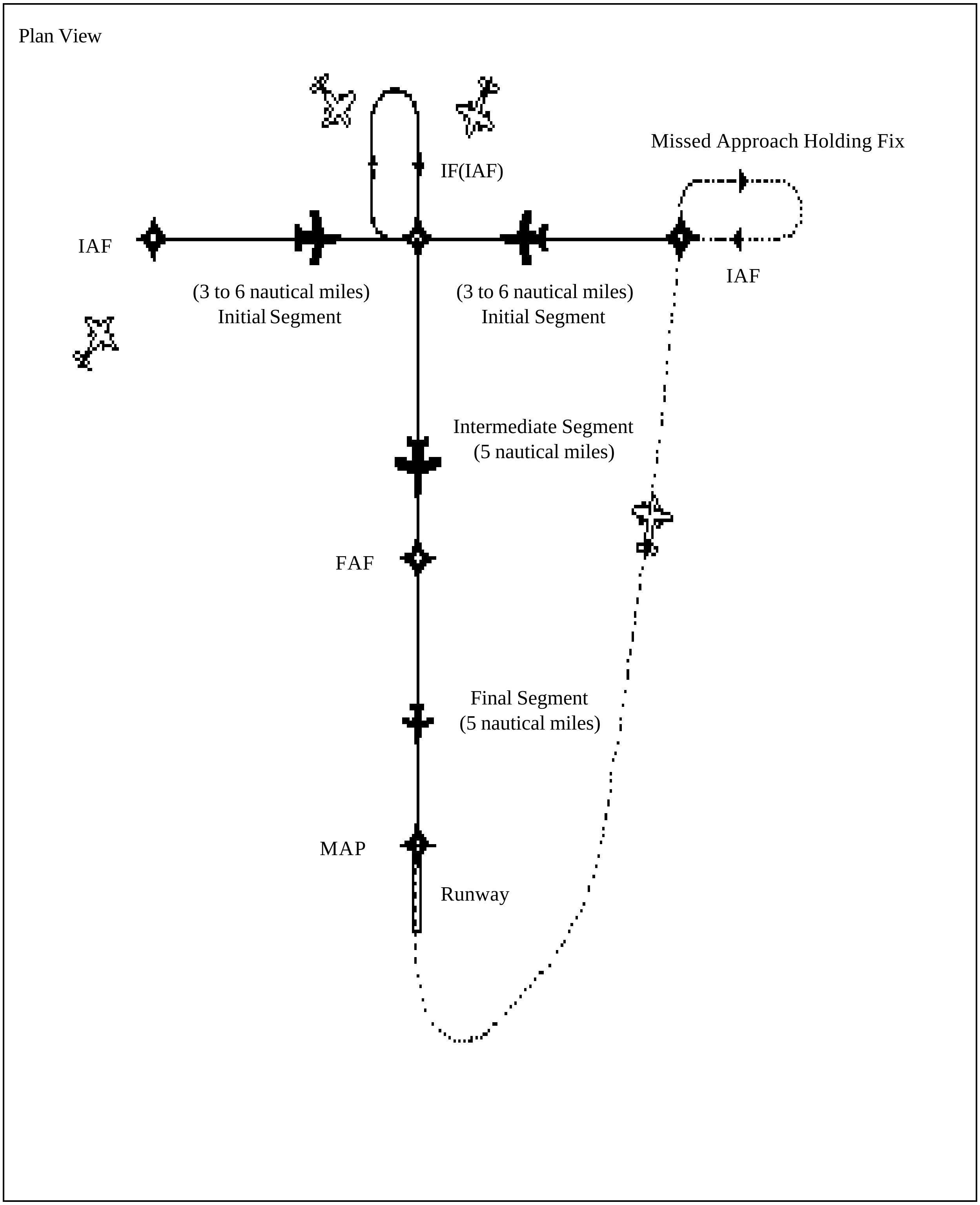


Figure 2.2

c. In order to accommodate descent from a high en route altitude to the initial segment altitude, the basic "T" configuration may be modified. When this occurs, a PT holding pattern provides aircraft an extended distance for the necessary descent gradient. The holding pattern constructed for this purpose is *always* established on the IF (IAF) waypoint. (See Figure 2-3.)

Modified Basic "T"

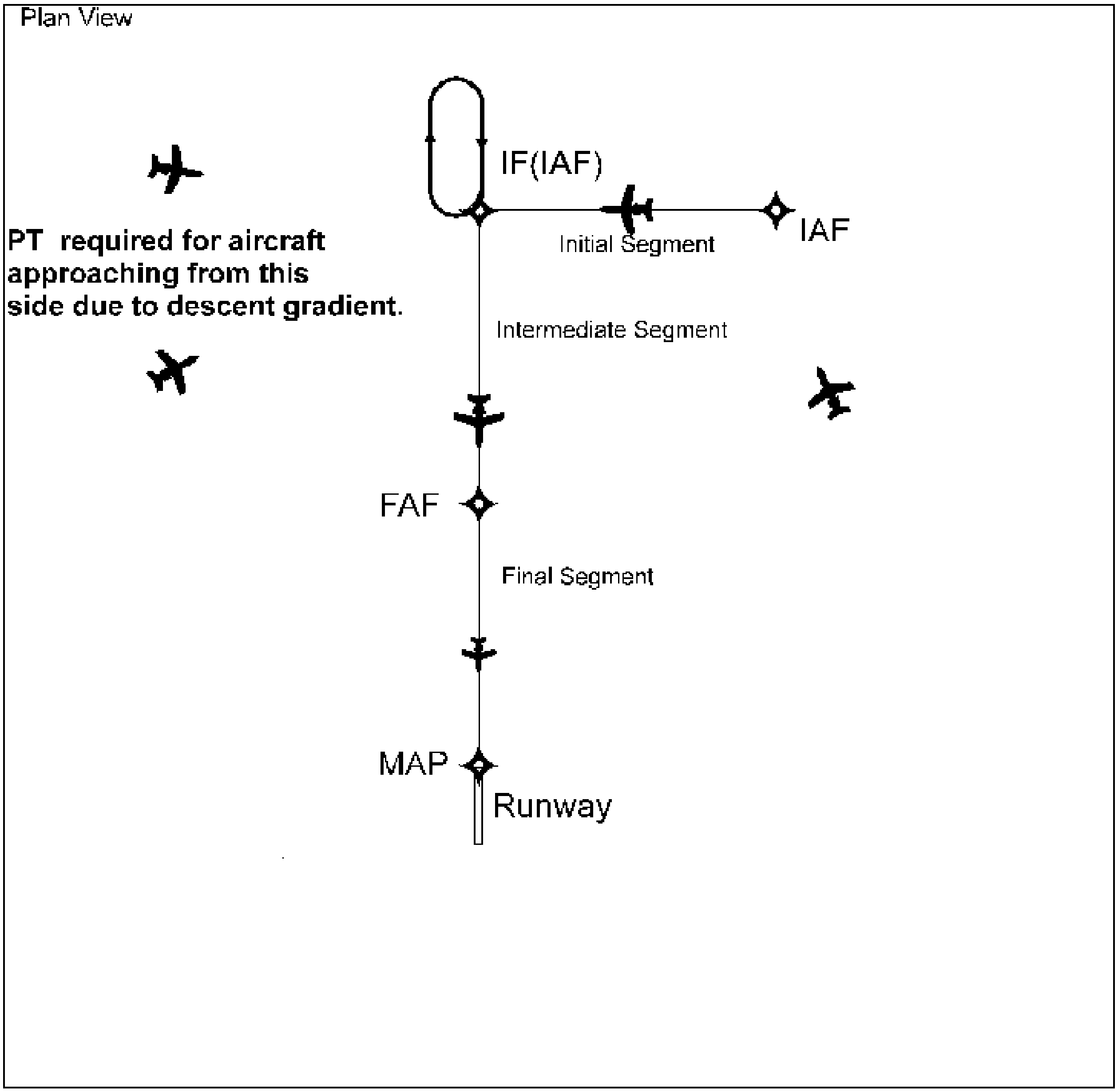
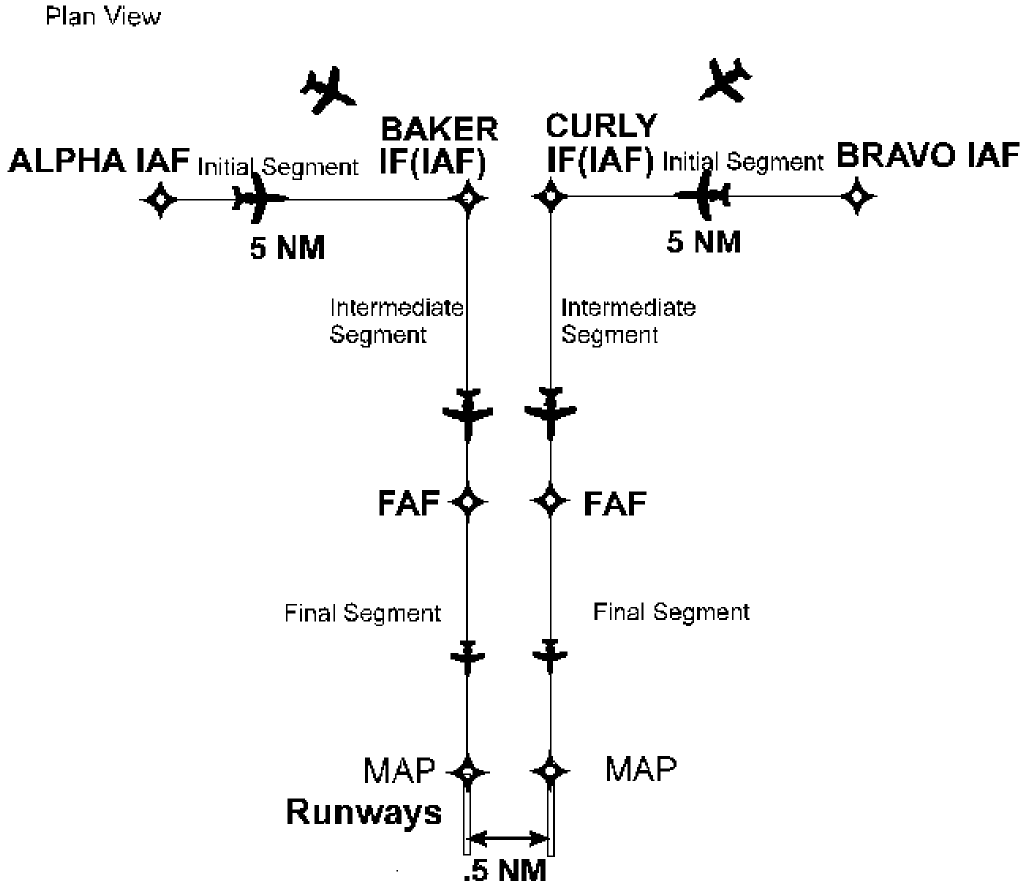


Figure 2.3

d. Another modification may be required for parallel runways. The normal “T” IAF’s serve all parallel runways (See Figure 2-4.)

Normal “T” for Parallel Runways



The normal "T" IAF's serve all parallel runways. Each runway will require a separate IF(IAF). Only one initial, intermediate and final segment combination will be depicted on the approach chart.

Figure 2.4

e. However, only one initial, intermediate and final segment combination will be depicted on the approach chart for the landing runway (See Figure 2-5 and Figure 2-6.)

Modified Basic "T"

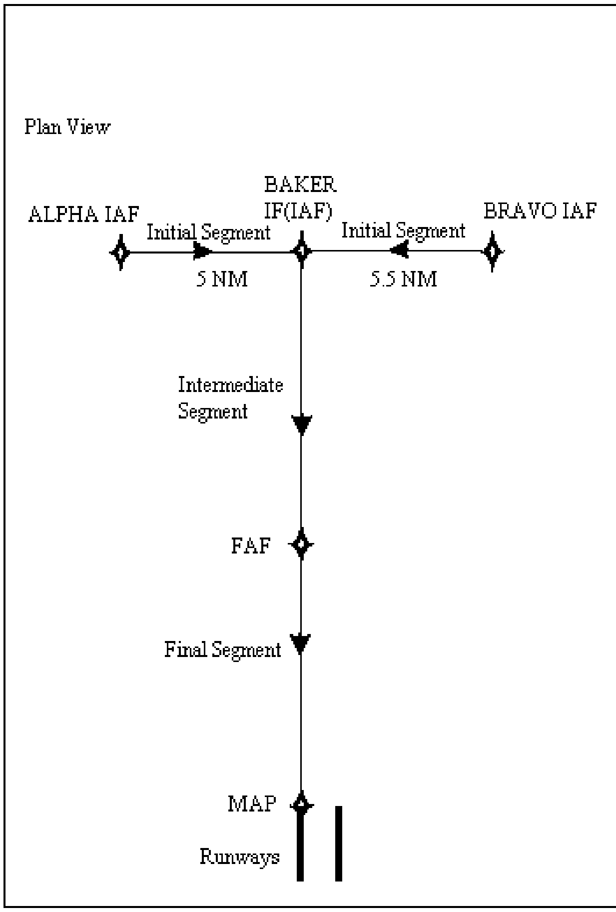


Figure 2.5

Modified Basic "T"

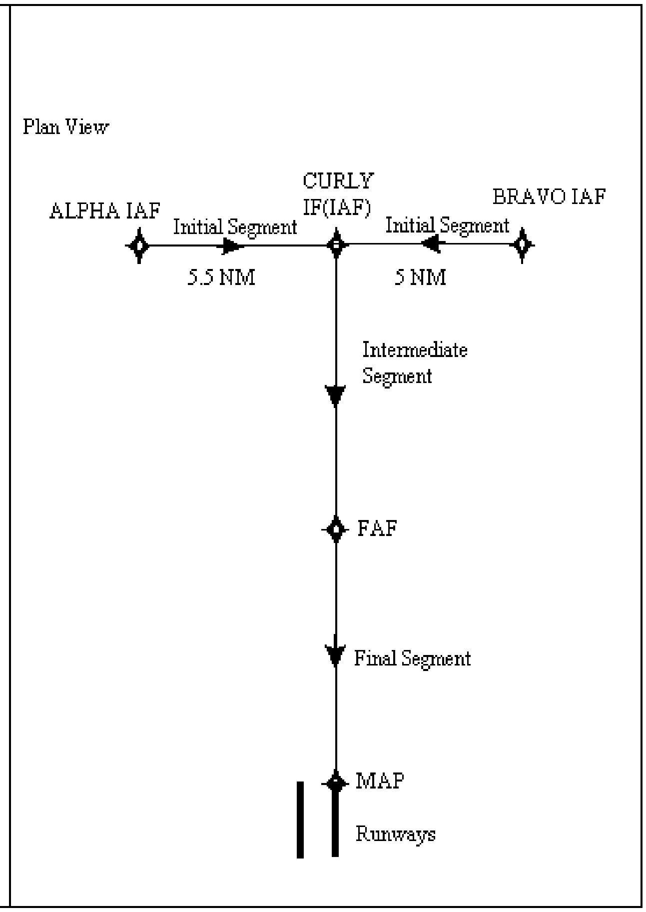


Figure 2.6

f. The standard TAA consists of 3 areas that are established by the extension of the legs of the basic "T". These areas are: the straight-in, left base and right base. The 30 NM arc boundary of each area is equivalent to a feeder fix. When crossing the boundary of each of these areas or when released by ATC, within the area, the pilot is expected to proceed direct to the appropriate waypoint IAF for the approach area being flown. A pilot has the option in all areas to proceed direct to the holding pattern for course reversal but must obtain a clearance from ATC unless the area is annotated "PT Required." The hold in lieu of procedure turn pattern at the IF (IAF) is standard. Area boundaries are magnetic course lines to the IF (IAF). The charted altitudes within the TAA are maintained by aircraft that traverse these areas. (See Figure 2-7.)

TAA Area

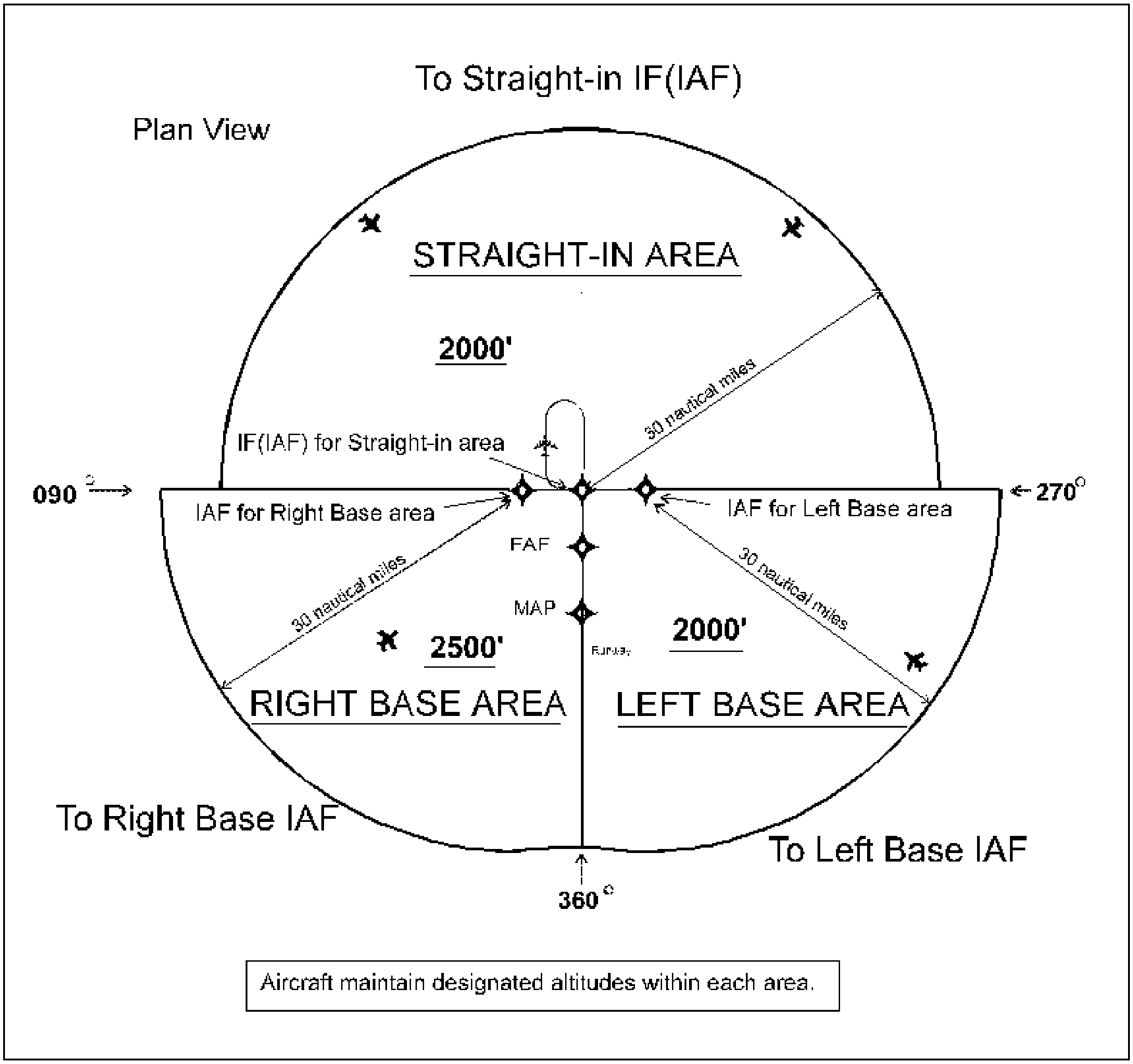


Figure 2.7

g. Normally, the minimum altitudes specified in the TAA and hold in lieu of procedure turn are the same. However, there may be locations where terrain or operational situations require minimum altitudes to be maintained within a sector of an area. In Figure 2-8, pilots flying into the right or left base areas are expected to maintain a minimum altitude of 6,000 feet MSL until within 17 NM of the appropriate IAF and then descend to the lower charted altitudes. Pilots approaching from the northwest are expected to maintain a minimum altitude of 6,000 feet MSL until within 22 NM of the IF (IAF) then descend to an altitude not lower than 2,000 feet MSL until reaching the IF (IAF).

Sectored TAA Areas

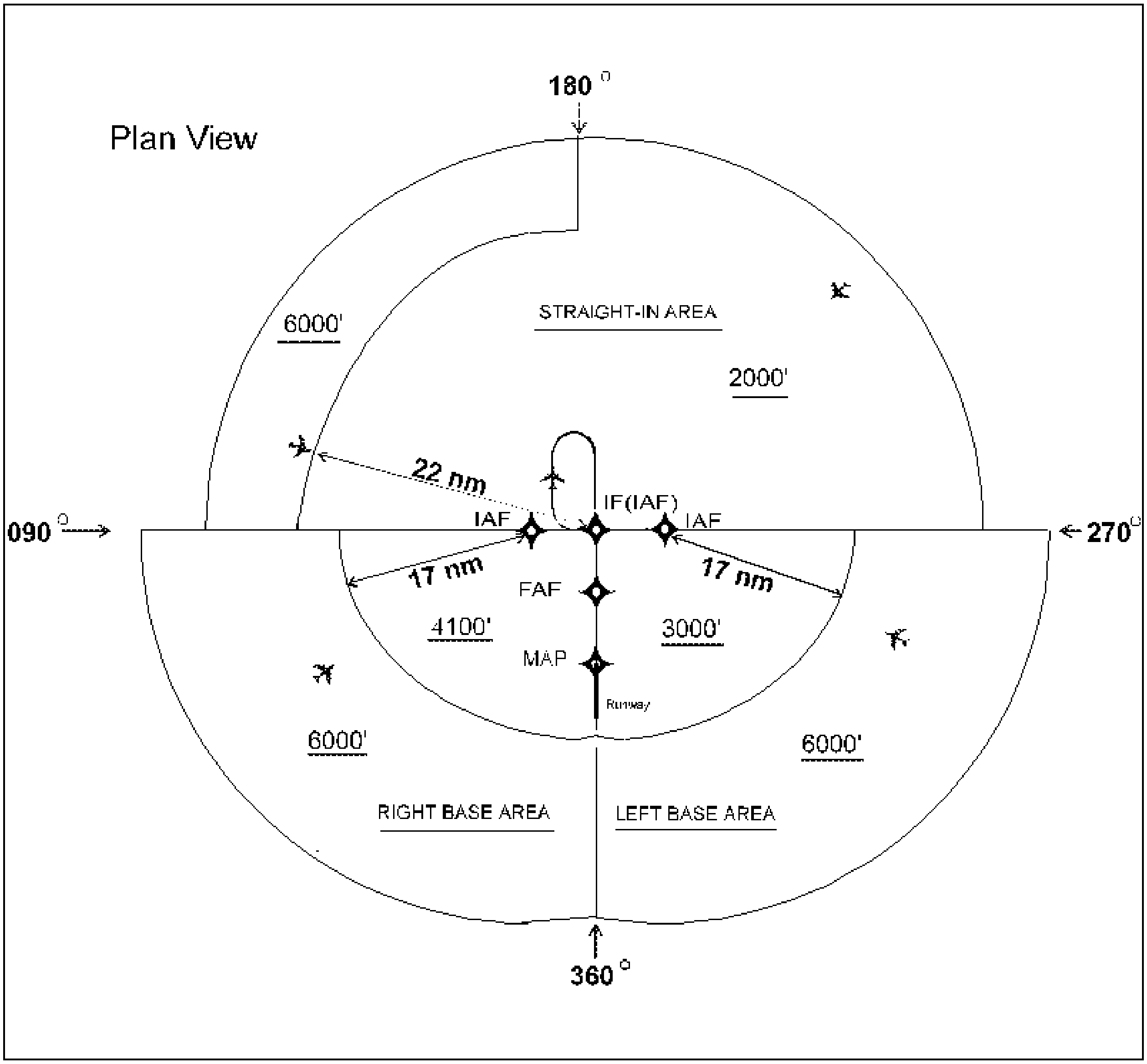


Figure 2.8

h. There may be modifications to the area of the standard TAA because of operational requirements. For example, the right or left base areas may be modified or eliminated. A hold in lieu of procedure turn pattern can be required when approaching from a certain area. Figure 2-9 is an example of this situation. Pilots approaching the IF (IAF) within 120° of the final approach course (this is the maximum intercept angle, a smaller angle could be required) are expected to fly a NoPT straight-in approach. If the PT is needed for unusual situations, advise ATC of your intentions. Pilots approaching the IF (IAF) on a course greater than 120° (or a specified smaller angle) from the final approach course are required to execute a procedure turn.

TAA with Left and Right Base Areas Eliminated

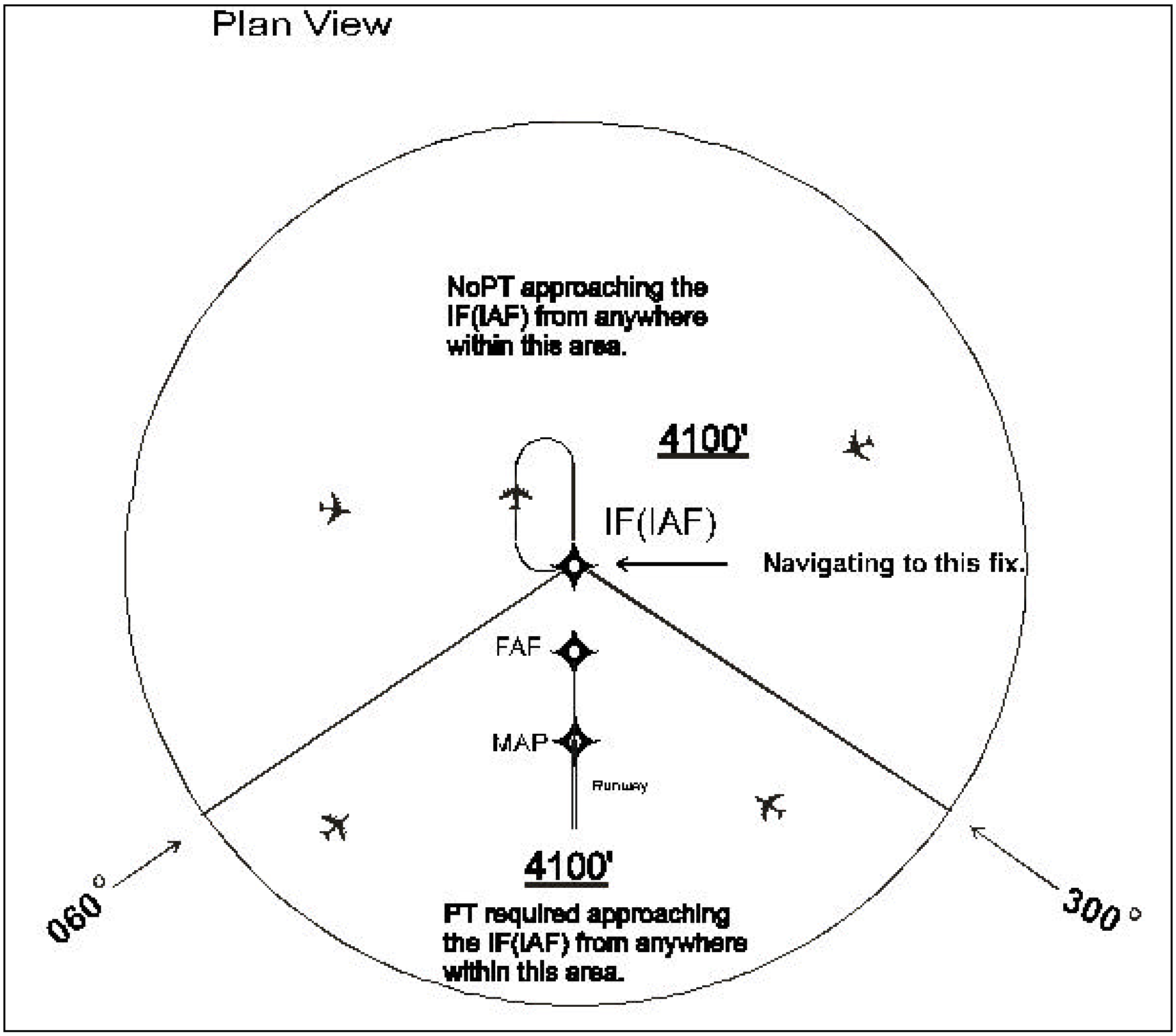


Figure 2.9

i. Figure 2-10 is an example of another modification. The right base is eliminated. Pilots approaching the IF (IAF) from between the courses of 360° clockwise to 060° are required to perform a PT. Pilots are expected to execute a NoPT straight-in approach when approaching the IF (IAF) from between the courses of 060° clockwise to 270°. The left base contains an IAF with an initial leg. NoPT is expected.

TAA with Right Base Eliminated

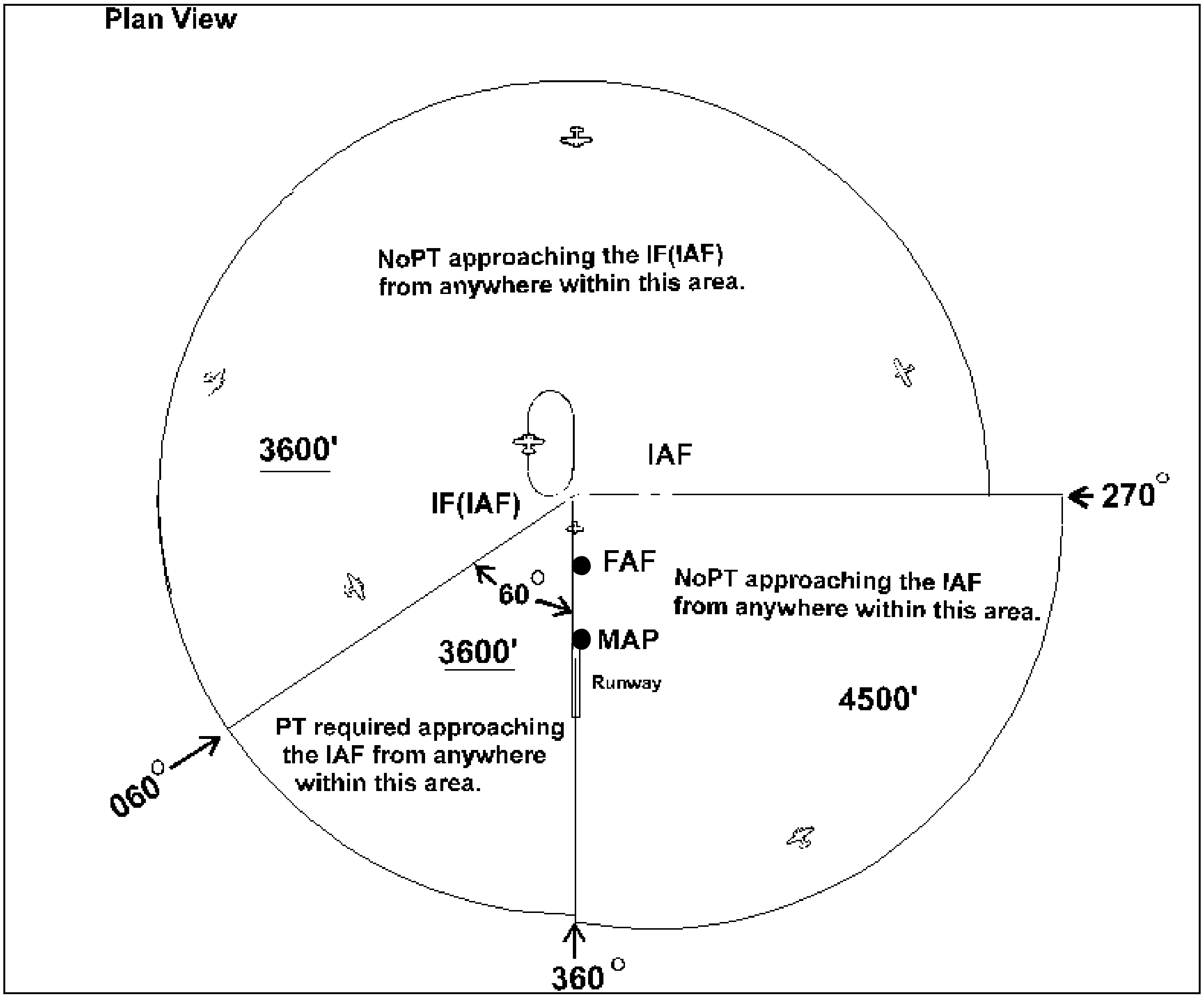


Figure 2.10

j. Normally an airway will overlie a TAA. Figure 2-11 is an example of all airways lying outside of the TAA. The required feeder routes are aligned with the appropriate IAF's of the "T".

TAA with Feeders from an Airway

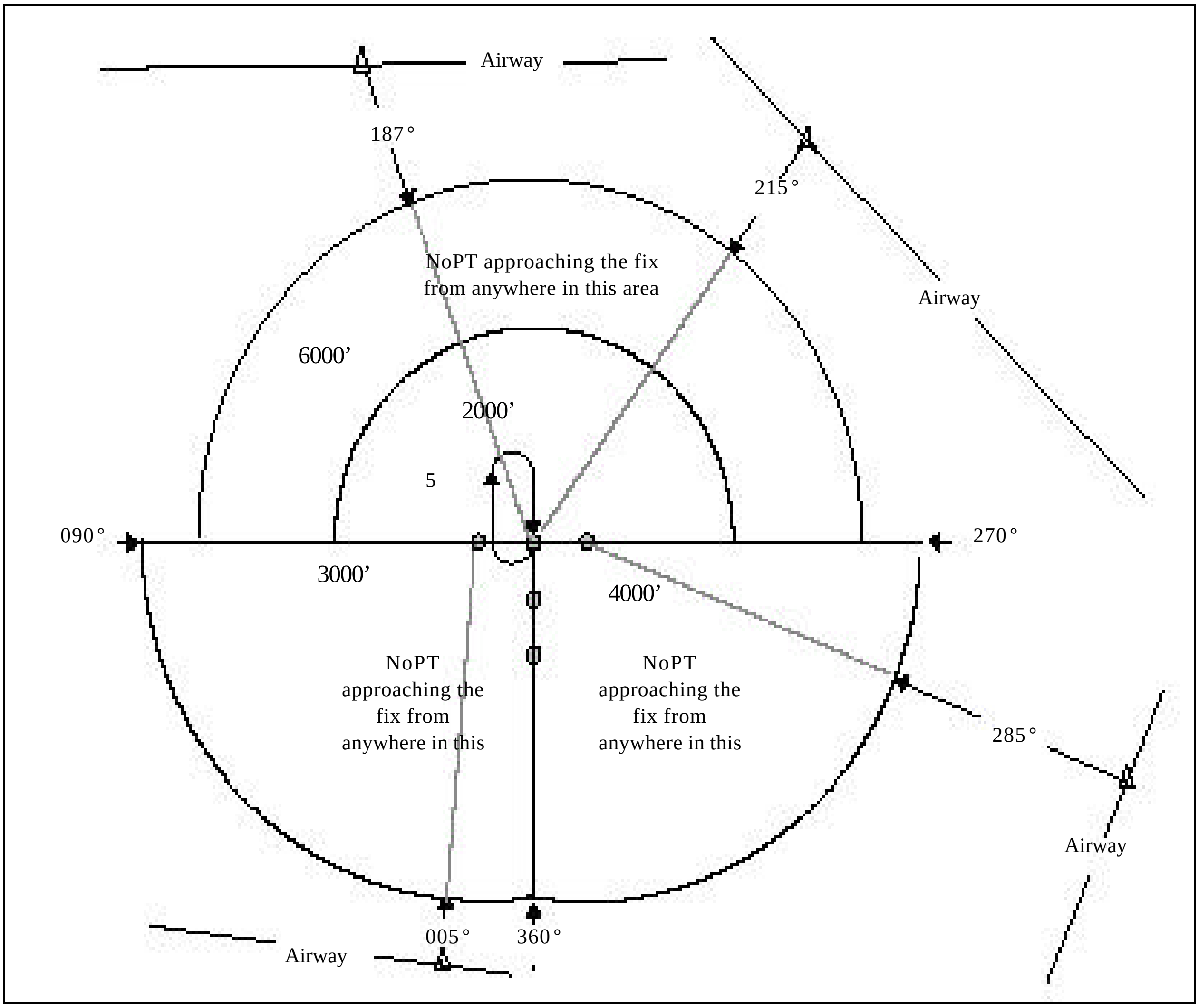


Figure 2.11

SECTION 3. GPS OUTSIDE THE NATIONAL AIRSPACE SYSTEM (NAS).

1. GENERAL. This section contains guidance for pilots and Operators for the installation and use of GPS equipment as a primary means of Class II navigation for oceanic/remote operations (including operations in North Atlantic MNPS airspace as per 14 CFR part 91, section 705) under IFR conditions. Emphasis is placed on the operational procedures and pilot actions required to safely operate in oceanic/remote airspace using GPS as a primary means of Class II navigation under IFR conditions.

2. PRIMARY MEANS OCEANIC/REMOTE OPERATIONS. Class II navigation Oceanic/remote operation is defined as that phase of flight between the departure and arrival terminal phases with an extended en route flight path over oceanic/remote areas outside the Operational Service Volume of ICAO standard airway navigation facilities. “Primary means of navigation” identifies navigation equipment which provides the only required means on the aircraft of satisfying the necessary levels of accuracy, integrity, and availability for a particular area, route, procedure or operation. The failure of a primary means of navigation will require reversion to dead reckoning. GPS equipment is acceptable for use as the primary means of navigation for Class II navigation in oceanic/remote areas using current separation standards. Using GPS however, requires the operator to follow unique pre-departure and en route procedures which are contained later on in this section.

3. EN ROUTE OCEANIC.

a. Oceanic operation is defined as that phase of flight between the departure and arrival terminal phases with an extended flight path over oceanic areas. In addition to the criteria outlined in this AC, the aircraft must be equipped with an approved long range navigation system appropriate for the intended route of flight. GPS may be used as a sole means of Class II navigation on oceanic/remote routes requiring either dual or single installations provided that the equipment is installed in accordance with the guidance contained in this AC.

b. GPS IFR operations in oceanic areas can be conducted as soon as the proper avionics systems are installed, provided all general requirements are met. Aircraft using GPS equipment under IFR must be equipped with an approved and operational alternate means of navigation (such as VOR, NDB, or an approved long range navigation system such as LORAN) appropriate for the intended route to be flown. Active monitoring (cross checking) of the alternate equipment is not necessary for installations which use RAIM for integrity monitoring. For these systems, active monitoring by the flightcrew is only required when the RAIM capability is lost.

> **Note: Outside of the National Airspace System (NAS), GPS may be used as a Long Range Navigation System (LRNS). On those routes requiring two long range navigation systems, a GPS installation with TSO-C129 authorization in Class A1, A2, B1, B2, C1, or C2 may be used to replace or supplement one of the other approved means of LRNS’s, such as one unit of a dual INS. On those routes requiring a single LRNS, a GPS unit which provides for integrity monitoring may be**

used as the LRNS and active monitoring of the alternate equipment is only required when the RAIM capability is lost. Additionally, GPS may be used as a primary means of Class II navigation on oceanic/remote routes requiring either dual or single installations provided that the equipment is installed in accordance with draft FAA Notice N 8110.GPS and that operators comply with the guidelines set forth in Appendix 3. Flight Standards Handbook Bulletin for Air Transportation, Number 95-02, "Guidance for Obtaining Operational Approval for the use of Global Positioning System (GPS) in the Conduct of Air Carrier Operations", provides the approval process for all GPS operations conducted by U.S. air carrier and commercial operators under 14 CFR 121 or 135 or by foreign air carriers under 14 CFR part 129. GPS may not be approved in other countries. Pilots should ensure that GPS is authorized by the appropriate sovereign state prior to its use within that state. Aircraft operating in oceanic/remote areas using GPS as a primary means system must comply with the installation guidance and the operational guidance contained in this AC.

4. INSTALLATION AND APPROVAL FOR GPS USED AS A PRIMARY MEANS OF NAVIGATION FOR OCEANIC/REMOTE OPERATIONS. The following guidance is provided for approving the installation of global positioning system (GPS) equipment to be used as a primary means of navigation for oceanic/remote operations (including minimum navigation performance specifications (MNPS) airspace). To clarify terminology, this guidance adopts the term "primary means of navigation" as opposed to "sole means of navigation" to identify navigation equipment which provides the only required means on the aircraft of satisfying the necessary level of accuracy, integrity, continuity and availability for a particular area, route, procedure or operation. The failure of a primary means of navigation may require reversion to a non-normal means of navigation (e.g., dead reckoning). Examples of systems which can provide a primary means of navigation include: very high frequency omnidirectional range (VOR) for domestic en route, terminal, and nonprecision approach where it is available; VOR/distance measuring equipment (DME) for domestic en route above flight level 240, terminal, and nonprecision approach where it is available; and inertial navigation systems (INS) for oceanic operation. The GPS installations which revert to another long-range navigator, such as INS, need not apply for GPS primary means approval; they may utilize GPS under supplemental Instrument Flight Rules (IFR) approval.

a. Performance Requirements. The following requirements must be met by the GPS equipment, in addition to the performance requirements of RTCA/DO-208, Minimum Operational Performance Standards for Airborne Supplemental Navigation Equipment Using Global Positioning System, as modified by Technical Standards Order (TSO)-C129. The approval process for evaluating compliance to these requirements is discussed in this Section.

(1) The GPS equipment must be capable of detecting and excluding a GPS satellite failure by means of a fault detection and exclusion (FDE) algorithm including receiver autonomous integrity monitoring (RAIM) for detection. The exclusion of a satellite failure must be automatic,

thus pilot action is not permitted to accomplish exclusion. The specific requirements of the exclusion function can be found in Appendix 4.

(2) In addition to FDE, the equipment must use an acceptable means to detect and exclude from the navigation solution, any satellite which is being tracked that experiences a failure which causes a pseudorange step function. The requirements for detection and exclusion of a pseudorange step function can be found in Appendix 4.

(3) The GPS equipment must exclude, without pilot action, any satellite designated unhealthy by any of the GPS navigation data. The satellite must be excluded within 5 minutes of the designation as unhealthy by the satellite. The specific requirements on what portions of the GPS navigation data shall be used to determine GPS health are contained later in this Section.

(4) If a GPS satellite failure results in loss of GPS navigation (due to the failure to exclude or a hard satellite failure which results in an inadequate number of satellites), an appropriate indication (TSO-C129, paragraphs (a)(3)(xiii)1c, (a)(4)(iv)10, and (a)(5)(iv)9) of the failure must be provided to the aircraft crew.

(5) The equipment must provide, upon request, an indication of the current estimate of position uncertainty in terms of NM. This estimate must be based on measurement inconsistency and must bound the true error with high confidence (approximately 99.9 percent). It is related to the test statistic calculated as part of FDE. This estimate will not be available if there are only four measurements available (because there is no redundancy). This output is intended to be used to provide information about the approximate magnitude of a potential positioning failure, when the horizontal integrity limit (HIL) exceeds the alert limit or when a positioning failure has been detected and not excluded.

(6) The loss of the long-range navigation function must be demonstrated to be improbable according to AC 23.1309-1A, Equipment, Systems, and Installations in part 23 Airplanes, or AC 25.1309-1A, System Design Analysis. For many oceanic/remote operations, this requirement must be met by equipping the aircraft with at least two (or more) independent (i.e., dual control display unit, dual GPS antenna, dual power sources, dual GPS sensors) navigation systems with a mean time between failures of at least 1000 hours each (for dual equipage).

(7) A prediction program is required to support operational departure restrictions. The specific requirements for this program are contained later in this Section.

b. Desired Performance. In addition to the required features described above, it is recommended that the GPS equipment provide the following features. These features increase the versatility and availability of the GPS receiver and may facilitate obtaining future operational benefits.

(1) The installed GPS equipment should be capable of acquiring and tracking satellites above a threshold that is at or below the horizon (no mask angle) in the oceanic/remote mode. However, the

introduction of this capability also incurs a requirement to provide an automatic and/or manual method of switching between the oceanic/remote mode of operation
(lower mask angle) and the standard mode of operation. If the selection is manual, the selected value must be continuously displayed to the flight crew and must not inhibit the required automatic changes specified in TSO-C129.

(2) The GPS equipment should provide an oceanic/remote mode of operation in which the alert limit for RAIM, as defined in RTCA/DO-208, can be increased up to 4 NM to improve FDE availability. Care must be taken in the design of the crew annunciations so that there is a clear distinction between loss of FDE availability and loss of navigation (this may be due to a detected satellite failure that cannot be excluded). The time-to-alert in the oceanic/remote mode of operation can be greater than 30 seconds, but shall not exceed 5 minutes.

(3) The GPS equipment should also continue to process the FDE algorithm when the internal HIL exceeds the alert limit in order to provide some level of integrity monitoring; any detected failure should be annunciated even if the HIL exceeds 4 NM. When the HIL is greater than 4 NM, the equipment must enunciate that integrity monitoring is inadequate (TSO-C129 paragraphs (a)(3)(xiii)2a, (a)(4)(iv)10, and (a)(5)(iv)9).

(4) During normal operation, the equipment should be capable of computing and displaying the current wind speed and wind direction.

(5) The GPS equipment should have the capability to accept forecast wind conditions at waypoints along a route in order to improve estimated time of arrival performance.

(6) The navigation system should include an automatic dead reckoning (DR) navigation mode that becomes active when GPS navigation capability is lost. The system, if provided, must include electronic inputs of true airspeed, altitude, and stabilized heading for use in generating the DR position. The system should use calculated winds from the last valid GPS data and incorporate the ability for the crew to input forecast winds. The system should be demonstrated to be capable of navigation with drift rates of no more than 14 NM per hour (assuming no wind changes).

(7) If the system provides a DR mode, then it should automatically revert to the dead reckoning mode when a GPS navigation solution cannot be provided, and should provide an alert to the pilot. The system should also allow the pilot to select DR when FDE has detected a satellite failure and the failure cannot be excluded. An indication that the system has reverted to dead reckoning mode must be continuously provided to the aircraft crew if the mode is provided. The dead reckoning mode of the GPS equipment shall retain the capability to couple with the flight guidance system (autopilot/flight director), if provided, and should not disconnect when switching between GPS and dead reckoning modes. The GPS equipment must automatically revert to normal navigation as soon as a navigation solution can be provided. Both transitions must be clearly annunciated (GPS to DR and DR to GPS).

c. Approval Process.

(1) The GPS equipment manufacturer or aircraft manufacturer obtains a TSO-C129 authorization (Class A1, A2, B1, B2, C1, or C2) from the cognizant Aircraft Certification Office (ACO). The manufacturer may also demonstrate compliance with the “performance requirements” and any additional “desired performance” functions as outlined above. The FDE prediction capability, as defined in this AC, must also be evaluated to comply with the requirements for accurately predicting the availability of the FDE algorithm. In this case, the aircraft certification office engineer should issue a separate letter of design approval, stating that the appliance (including part number) and software prediction program (including revision number) has been found to comply with this notice. It is assumed that the appliance will be manufactured under a TSO authorization (TSOA). Alternatively, the applicant must demonstrate that the performance requirements of TSO-C129 are met as part of the installation approval.

(2) The applicant obtains installation approval of the GPS navigation system via the amended Type Certificate (TC) or Supplemental Type Certificate (STC) certification process. An acceptable means of compliance to determine airworthiness can be found in AC 20-138, Airworthiness Approval of Global Positioning System (GPS) Navigation Equipment for Use as a VFR and IFR Supplemental Navigation System, or AC 20-130A, Airworthiness Approval of Navigation or Flight Management Systems (FMS) Integrating Multiple Navigation Sensors.

(a) If the manufacturer has previously obtained a TSOA and obtained a letter of design approval as described in paragraph 6a of this notice, no additional testing is required beyond that outlined in AC 20-138 or AC 20-130A.

(b) If the manufacturer has not obtained a TSOA or letter of design approval as described in this AC, then the *applicant* must demonstrate compliance with the “performance requirements” and any additional “desired performance” functions as outlined above. The FDE prediction capability must also be evaluated to comply with the requirements to accurately predict the availability of the FDE algorithm.

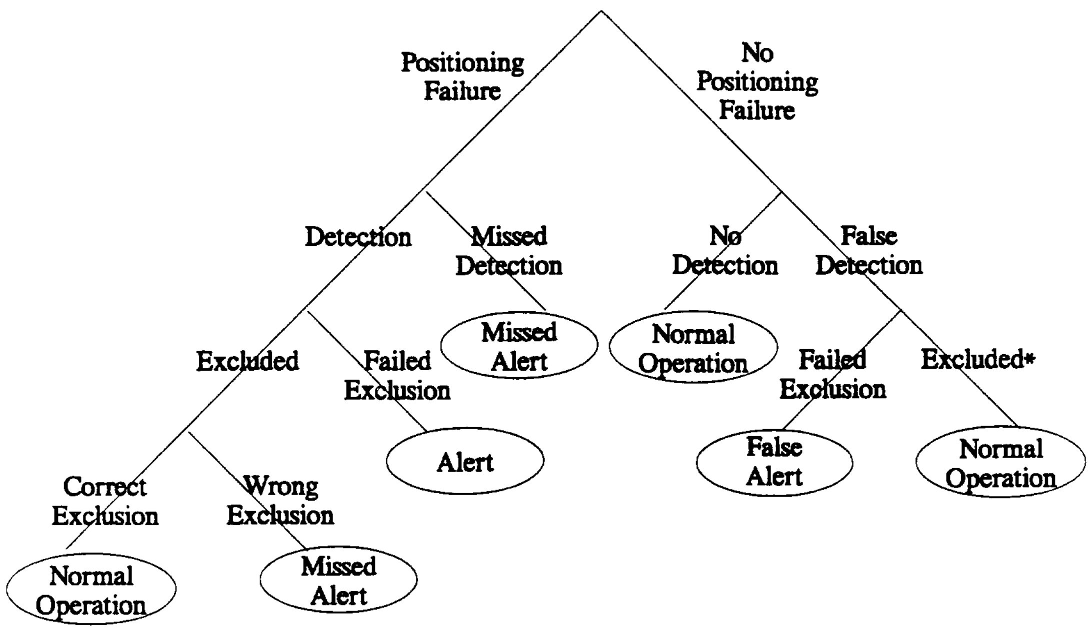
(c) Once the installation has been approved, the aircraft flight manual supplement (AFMS) must be updated to state: “The XXX GPS equipment as installed has been found to comply with the requirements for GPS primary means of navigation in oceanic and remote airspace, when used in conjunction with the XXX prediction program. This does not constitute an operational approval.” Appropriate operational procedures assumed for aircraft certification, as well as procedures for operating any additional features (such as dead reckoning) must be identified in the AFMS. These procedures must include the use of the FDE prediction algorithms.

(d) The FAA Form 337, Major Alteration or Repair, process may be used for follow-on installations of the same navigation system for which there is a TC or STC in the same model aircraft and the engineering data developed for the initial certification is used to accomplish the follow on installation approval.

(e) The applicant should be aware that an operational approval must be obtained before conducting Class II navigation (remote/oceanic). Applicants should contact the appropriate Flight Standards District Office to seek approval.

5. REQUIREMENTS FOR FAULT DETECTION AND EXCLUSION (FDE). GPS equipment shall have a fault detection and exclusion (FDE) capability that utilizes GPS measurements to provide independent integrity monitoring. The detection function refers to the capability to detect a satellite failure which affects navigation, while the exclusion function refers to the capability to exclude one or more failed satellites from the solution and prevent a satellite failure from affecting navigation. The FDE algorithm must meet the following requirements under the standard assumptions of GPS performance as specified in this AC. The detection and exclusion functions must be accomplished without pilot interaction. The FDE algorithm must be aided by barometric altimetry measurements, as required by TSO-C129. Additional augmentations (such as clock aiding) are not precluded.

a. FDE terms and event relationships. In order to assist in the understanding of FDE terminology, the following schematic depiction (Figure 3.1) illustrates a fault tree relating FDE events. The events are further defined below.



*****Wrong exclusion is not possible, since there is no real failure to incorrectly exclude.

Figure 3.1.

b. FDE Definitions.

(1) Alert. An alert is defined to be an indication that is provided by the GPS equipment that the navigation performance achieved by the equipment is not acceptable. The conditions for this alert are defined below. Note that an alert refers only to those indications that are provided by the sensor, and does not refer to any internal processing associated with the FDE algorithm.

(2) Horizontal Alert Limits. The horizontal alert limit for oceanic/remote navigation mode is defined to be at least 2 NM, but shall not exceed 4 NM. RTCA/DO-208 specifies a limit of 2 NM, but a higher limit of 4 NM increases availability and is adequate for oceanic/remote operation.

(3) Time-to-Alert. The time-to-alert for oceanic/remote navigation mode is defined to be at least 30 seconds, but shall not exceed 5 minutes. RTCA/DO-208 specifies a time-to-alert of 30 seconds, but a higher time-to-alert of 5 minutes increases availability and is adequate for oceanic/remote operation.

(4) Positioning Failure. A positioning failure is defined to occur whenever the difference between the true position and the output position exceeds the applicable horizontal alert limit.

(5) Missed Detection. A missed detection is defined to occur when a positioning failure is not detected (internal to the FDE algorithm).

(6) False Detection. A false detection is defined to occur when a positioning failure does not exist, but a failure is detected (internal to the FDE algorithm).

(7) Wrong Exclusion. A wrong exclusion is defined to occur when a positioning failure is detected and the positioning failure still exists, but is undetected after exclusion, resulting in a missed alert.

(8) Missed Alert. Positioning failures which are not annunciated (as an alert) within the time-to-alert are defined to be missed alerts. Both missed detection and wrong exclusion conditions are missed alerts.

(9) False Alert. A false alert is defined as the indication of a positioning failure when a positioning failure has not occurred.

NOTE: The term, *false alert,* refers to actual alerts that are issued by the GPS equipment.

(10) Horizontal Integrity Limit. The horizontal integrity limit (HIL) is the radius of a circle in the horizontal plane, with its center being at the indicated position, which describes the region which is assured to contain the true position. It is the horizontal region for which the missed alert and false alert requirements can be met. It is only a function of the satellite and user geometry and the expected error characteristics: it is not affected by actual measurements. Therefore, this value is predictable.

(11) Availability of Detection. The detection function is defined to be available when the constellation of satellites provides a geometry for which the missed alert and false alert requirements can be met on all satellites for the alert limit and time-to-alert. When the constellation is inadequate to meet these requirements, the fault detection function is defined to be unavailable. Thus the availability

of detection for a specific time, location, and constellation is defined to be the product of satellite-specific terms, as follows:

$$\text{Detection Availability} = \prod_{i=1}^{N} D(i),$$

where N = number of satellites used in the sensor,
D(i) =1, if Pr(detection given i~ satellite failed) $\geq$ 99.9% and Pr(false alert) < 0.002/hour
0, if Pr(detection given i~ satellite failed) < 99.9% or Pr(false alert) > 0.002/hour.

NOTE: For a given geometry and navigation mode, the detection function is either available or unavailable. The detection function is expected to operate whenever sufficient measurement redundancy exists, even when the probability of missed alert cannot be assured for the alert limit. Therefore, it may operate when the missed detection rate is greater than required for the alert limit, but the false alert rate must continue to meet requirements.

(12) Failed Exclusion. A failed exclusion is defined to occur when a true satellite failure is detected and the detection condition is not eliminated within the time-to-alert (from the onset of the positioning failure). A failed exclusion results in an annunciation of a detected satellite failure. A failed exclusion does not imply that the exclusion must be correct, only that it eliminates the detection condition and therefore prevents an indication of loss of integrity monitoring. The probability of false exclusion is included in the probability of missed alert. In addition, failed exclusion of false internal detections are not included, because they are included in the false alert rate.

(13) Availability of Exclusion. The exclusion function is defined to be available when the constellation of satellites provides a geometry for which the FDE algorithm can meet the failed exclusion requirement, and prevent the indication of a positioning failure or a loss of integrity monitoring function. Therefore, exclusion must occur before the duration of a positioning failure exceeds the time-to-alert, and the detection function as defined above must be available after exclusion. Note that for a given geometry and a given failed satellite, the success of the exclusion function to prevent an alert condition (duration of positioning failure exceeds time-to-alert) may be probabilistic. For example: given a particular exclusion algorithm, a satellite geometry, and a failed satellite, the algorithm could have a 99 percent probability of successfully preventing a warning condition. However, the exclusion function is only defined to be available if the probability of excluding a satellite and preventing an alert (given a satellite failure has occurred and has been detected) satisfies the failed exclusion requirement. Thus the availability of exclusion for a specific time, location, and constellation is defined to be:

$$\text{Exclusion Availability} \prod_{i=1}^{N} E(i),$$

where N = number of satellites used in the sensor,
E(i) = 1, if Pr(failed exclusion) $\leq 10^{-3}$ given i^{th} satellite failed,
0, if Pr(failed exclusion) $> 10^{-3}$ given i^{th} satellite failed.

NOTE: For a given geometry and navigation mode, the exclusion function is either available or unavailable. The exclusion function is expected to operate whenever sufficient measurement redundancy exists, regardless of whether or not it is "available" by the definition above. Therefore, it may operate when the missed detection rate is greater than required for the appropriate alert limit, but the false alert rate must continue to meet requirements.

c. FDE Requirements.

(1) Missed Alert Probability. The probability of missed alert shall be less than or equal to 0.001 for every geometry and every navigation mode. If this requirement is not met for a given geometry, then the detection function is defined to be unavailable for that geometry. This requirement is on the missed alert rate external to the GPS equipment. When related to the internal algorithm, it includes both probabilities of missed detection and false exclusion.

(2) False Alert Probability. The probability of false alert shall be less than or equal to 0.002/hour. If this requirement is not met for a given geometry, then the detection function is defined to be unavailable for that geometry. Note that a false alert rate of 10^{-5} is more consistent with the requirement for loss of navigation. This requirement is relaxed to the RTCA/DO-208 requirement for oceanic operations, since the duration of the false alert will be short. This requirement is on the false alert rate external to the GPS equipment. When related to the internal algorithm, it includes both probabilities of false detection and the failure to exclude the false detection.

(3) Failed Exclusion Probability. The probability of failed exclusion shall be less than or equal to 10^{-3} for every geometry and every navigation mode for which exclusion is implemented. Exclusion must be implemented for the oceanic mode. If this requirement is not met for a given geometry, then the exclusion function is defined to be unavailable for that geometry. This requirement is on the alert rate external to the GPS equipment due to failed exclusion. It is equivalent to the probability that a positioning failure is annunciated when a GPS satellite failure occurs and is detected internally.

(4) For some algorithms, this probability may be zero in that exclusion is always conducted when a failure is detected. However, note that such an algorithm must also meet the missed detection requirement above, which includes the probability of false exclusion.

d. GPS Standard Assumptions.

(1) Selective Availability. Selective Availability (SA) shall be modeled as the sum of:

(a) a second-order Gauss-Markov process with an auto-correlation time of 120 seconds and a standard deviation of 23 m, and

(b) a random constant with normal distribution, a mean of zero and a standard deviation of 23 m. The SA processes on all satellites are to be statistically independent. When modeling a single independent SA sample (for a single snapshot or for samples greater than 2 minutes apart), SA can be modeled by a Gaussian random variable with a mean of zero and a standard deviation of 30.5 m. Note that any additional errors must be added to this model, yielding a typical value of 33 m.

(2) Satellite Failure. The probability of a satellite integrity failure is 10^{-4} per hour for the GPS position solution (based on 3 satellite major service failures/year/constellation, assuming 8 satellites in view). A satellite integrity failure is defined to be a failure that can contribute to a hazardously misleading situation. For the purpose of testing, a slow-ramp failure of 5 meters/second may be used as described in RTCA/DO-208, paragraph 2.5.2.5.2.2.

6. STEP DETECTOR REQUIREMENTS.

a. Step Detector.

(1) The equipment shall detect a pseudorange step error greater than 1000 meters, including steps which cause loss of lock for less than 10 seconds. A pseudorange step is defined to be a sudden change in the measured distance to a satellite. It can be written as:

$$PR_{STEP} = | PR_{PREDICTED} - PR_{MEASURED} |,$$

where $PR_{PREDICTED}$ is the predicted pseudorange at the time of measurement, based on previous measurements, and $PR_{MEASURED}$ is the pseudorange at the time of the measurement.

(2) If a pseudorange step is detected for a satellite, that satellite shall be excluded from use in the navigation algorithm until its integrity can be verified through fault detection (RAIM). The manufacturer is free to choose any method to calculate the predicted pseudorange. However, any method used should properly take into account satellite movement and aircraft dynamics up to a groundspeed of 750 knots (kts) and accelerations up to 14.7 meters/second/second (1.5 g's).

7. REQUIREMENTS FOR USING GPS NAVIGATION DATA. In addition to monitoring by using FDE and the step detector, the GPS equipment shall monitor the GPS navigation data to detect any of the following conditions within 5 minutes of the onset of the condition. Any satellite which meets any of the following criteria shall not be used for navigation for the duration of the condition.

a. Ephemeris health word in subframe 2 or 3 set to the "not healthy" state.

b. Failure of parity on 3 successive words.

c. User range accuracy (URA) of 128 meters or more.

d. Bit 18 of the hand-over word (HOW) set to 1.

e. Default navigation data is being sent (alternate 0's and l's).

f. Navigation data is all 1's (could inadvertently cause all satellites to be declared unhealthy).

g. Mismatching issue of data ephemeris (IODE) and issue of data clock (IODC).

8. REQUIREMENTS FOR FDE PREDICTION ALGORITHM.

a. A prediction program is required to support the operational requirement for a predeparture outage check. This prediction program can be provided on any processing platform (in the GPS equipment or not), but it must employ an identical FDE algorithm as the one that is utilized in the GPS equipment.

b. The prediction program must have the capability to manually designate GPS satellites which will be out of service during the operation. This will include GPS satellites scheduled to go out of service for maintenance, as well as satellites already out of service (if the program does not have access to that information directly through a GPS receiver and the almanac data).

c. The prediction program must have the capability for the operator to designate a route, defined by a series of waypoints. It must also allow for designation of a departure time and expected ground speeds. Since specific ground speeds may not be maintained, this pre-flight check will have to be performed for a range of ground speeds (expected ground speed ±100 kts in 20 kt increments). Finally, it must allow for the entry of the route spacing, centerline to centerline, on the intended oceanic/remote route. This information will be used to determine the maximum length of an outage on the intended route.

d. For the route that is specified, the program must determine and output a bound for the outage durations specified below. This bound must be accurate for the complete range of flight times/speeds. Note that this requirement is not intended to imply that the equipment must always compute these parameters in real time. This information may be precompiled and available via a look-up table within the equipment. For example, if the maximum worldwide outage with 24 satellites operating were 30 minutes, then the equipment could use that information as a conservative bound of the actual performance. Another example is the reduction in the velocity variation computation; if the applicant only computes the boundary conditions, and can prove that the conditions which are evaluated truly are the boundary conditions, then no additional calculations would be necessary.

(1) The maximum outage duration of the loss of fault exclusion to within 5 minutes. An outage of exclusion is defined to occur when the exclusion function is unavailable.

(2) The maximum outage duration of the capability to navigate (provide a position solution) to within 5 minutes.

e. If the maximum outage of exclusion (in hours) is greater than half the route spacing (in NM) divided by 35 or there is an outage of the ability to navigate, the program shall indicate that the operation should not be conducted.

f. This program can be used by the operator for planning purposes, and will be used prior to departure to determine if GPS has sufficient availability to conduct the operation.

9. PRE-DEPARTURE PROCEDURES. In addition to the equipment performance standards described above, GPS primary means oceanic/remote operations must be augmented by the following pre-departure requirements.

a. All operators conducting GPS primary means oceanic/remote operations under part 91 and 14 CFR part 125 and air carrier operations conducted under part 121, 135, and 129 must have access to an FAA approved FDE prediction program that is capable of predicting, prior to departure, the maximum outage duration of the loss of fault exclusion, the loss of fault detection and the loss of navigation function for flight on a specified route.

b. The "specified route of flight" is defined by a series of waypoints (to include the route to any required alternates) with the time specified by a velocity or series of velocities. Since specific ground speeds may not be maintained, the pre-departure prediction must be performed for the range of expected ground speeds. This FDE prediction program must use the same FDE algorithm that is employed by the installed GPS equipment and must be developed using an acceptable software development methodology (e.g., RTCA/DO-178B). The FDE prediction program must provide the capability to designate manually satellites that are scheduled to be unavailable in order to perform the prediction accurately. The FDE prediction program will be evaluated as part of the navigation system's installation approval. The requirements for the FDE prediction algorithm are outlined in this AC.

c. Prior to departure, the operator must use the FDE prediction program to demonstrate that there are no outages in the capability to navigate on the specified route of flight (the FDE prediction program determines whether the GPS constellation is robust enough to provide a navigation solution for the specified route of flight). Any predicted outages in the capability to navigate on the specified route of flight will requires cancellation, delay, or re-routing of the flight.

d. A failed satellite does not necessarily cause a loss of navigation function. The GPS equipment must be capable of detecting and excluding a failed satellite from the navigation solution. Therefore, It is possible that there will be no affect on the ability of the equipment to navigate given a failed satellite. However, If the equipment cannot exclude the failed satellite, then the accuracy of the equipment could be degraded. In this case, the equipment is required to provide an estimate of position uncertainty.

e. Once navigation function is assured (the equipment can navigate on the specified route of flight), the operator must use the FDE prediction program to demonstrate that the maximum outage of the capability of the equipment to provide fault exclusion for the specified route of flight does not exceed the acceptable duration (fault exclusion is the ability to exclude a failed satellite from the navigation solution). The acceptable duration (in minutes) is equal to the time it would take to exit the protected airspace (one-half the lateral separation minimum) assuming a 35 nautical mile per hour cross-track navigation system error growth rate when starting from the center of the route. For example, a 60 nautical mile lateral separation minimum yields 51 minutes acceptable duration (30 NM divided by 35 NM per hour). If the fault exclusion outage exceeds the acceptable duration, the flight must be canceled, delayed or re-routed.

10. PILOT PROCEDURES. The following pilot procedures should be included in the Operator's appropriate manuals and training programs:

a. The pilot will report degraded navigation capability to ATC in accordance with section 91.187. Additionally, flight crewmembers operating under part 121 and part 135 will notify the appropriate dispatch facility of any degraded navigation capability in accordance with the air carrier's FAA approved procedures.

b. If the pilot receives an indication of a fault detection function outage (RAIM is not available), navigation integrity must be provided by comparing the GPS position with a position computed by extrapolating the last verified position with true airspeed, heading, and estimated winds. If the positions do not agree to within 10 NM, the pilot should immediately begin using dead reckoning procedures until the exclusion function or navigation integrity is regained.

c. If the pilot receives a fault detection alert (failed satellite), the pilot may choose to continue to operate using the GPS generated position if the current estimate of position uncertainty from the FDE algorithm is actively monitored. If this number exceeds 10 NM or is not available, the pilot should immediately begin using dead reckoning procedures until the failed satellite is excluded.

d. If the pilot receives a loss of navigation function alert, the pilot should immediately begin using dead reckoning procedures until GPS navigation is regained.

SECTION 4. AIRBORNE NAVIGATION DATABASES.

1. REQUIREMENT FOR A DATABASE. To conduct IFR operations using GPS equipment to navigate in the U.S. NAS and oceanic airspace, the aircraft GPS equipment must include an updatable navigation database. That database will support en route and terminal operations; or en route, terminal, and GPS nonprecision instrument approach operations. The database must be current to fly GPS approaches and to use GPS in lieu of ADF and DME.

a. Geographic Area of Content. Airborne navigation databases contain data covering the geographic areas where GPS navigation systems have been certified for IFR use. Data may cover large geographic areas or small user-defined areas within the U.S. NAS and related oceanic areas.

b. Database Description. GPS airborne navigation databases are provided initially by the receiver manufacturer and updated by the manufacturer or a designated data agency. The databases contain records of location information by latitude and longitude to a resolution of 0.01 minutes or better (0.01 seconds for approaches) for the area(s) in which IFR operations are approved. The database is user selectable which allows the pilot to make specific selections during flight operations to support navigational needs. The database may also be user defined in that the information is tailored to the requirements of a user.

> **Note: Manual entry/update of data in the navigation database shall not be possible. This requirement does not prevent the storage of "user-defined data" within the equipment.**

c. Update of Data. Waypoint information is provided and maintained by the National Flight Data Center (NFDC). The data is typically updated at regular intervals such as the internationally agreed upon Aeronautical Information Regulation and Control (AIRAC) cycle of every 28 days.

d. Geodetic Reference Datum. The GPS equipment derives position information referenced to the World Geodetic System of 1984 (WGS-84). Databases produced for use in the contiguous United States, Alaska, and Hawaii contain coordinates of location information referenced to the North American Datum of 1983 (NAD 83). For this AC, coordinates of locations referenced to NAD 83 are compatible with the coordinates of the same locations referenced to WGS-84.

2. EN ROUTE (OCEANIC AND DOMESTIC) AND TERMINAL NAVIGATION. Navigation databases supporting GPS equipment certified for en route (including en route oceanic and en route domestic) and terminal operations contain, as a minimum, all airports, VORs, VORTACs, NDBs, and all named waypoints and intersections shown on en route and terminal area charts, DPs, and STARs. The databases incorporate information from the geographic areas of the contiguous United States, Alaska, Hawaii, and surrounding coastal waters including waypoints and intersections for oceanic flight between the United States and Hawaii. For oceanic flights outside the NAS, user selectable data is available for most GPS receivers.

a. In the terminal area, the database will include waypoints for DP's and STAR's as well as other flight operations from the beginning of a departure to the en route structure or from an en route fix to the beginning of an approach procedure.

b. All named waypoints are identified with a five-letter alpha character name provided by the NFDC. Waypoints unnamed by the NFDC, such as a DME fix, are assigned a coded name in the database (refer to the sample approach charts in Appendix 3).

c. Waypoint latitude and longitude coordinates are typically displayed in degrees, minutes, and tenths of minutes or hundredths of minutes. However, this may vary between equipment manufacturers.

3. INSTRUMENT APPROACH PROCEDURE NAVIGATION. In addition to the data which supports en route and terminal operations, a navigation database that supports GPS overlay nonprecision instrument approaches (except localizer, LDA, and SDF) contains coordinates for the waypoints, fixes, and NAVAIDs published in 14 CFR part 97, Standard Instrument Approach Procedures. Special instrument approach procedure data may be included at the request of those operators authorized to use the procedures. Data for approach procedures into military airports also may be included if the procedures are available, and authorized for civil operations. In addition, all waypoints to support GPS stand alone approaches are also contained in the database.

4. THE GPS APPROACH OVERLAY PROGRAM. The navigation database coding should not change during any phase of the GPS Approach Overlay Program, except for modifications necessary to support changing rules and/or technology. Approaches coded into the database are limited to U. S. airspace. Approaches for other airspace will not be included until authorized by the FAA as well as the appropriate sovereign authority. Whether or not an approach is included in the database depends on its codability and flyability using GPS equipment. Therefore, part 97, military, and special approaches are classified into codable and non-codable nonprecision instrument approaches.

> **Note: An aircraft is not authorized to fly any IFR approach using GPS unless that instrument approach procedure is retrievable from the manufacturer's supplied navigation database.**

a. Codable Approach Procedures. The navigation database contains latitude and longitude coordinates for waypoints, fixes, and NAVAIDs for those part 97 civil use, and military, nonprecision approaches considered codable for database purposes and considered safe to fly by the FAA using normal piloting techniques. Special approaches may be included at authorized user request.

b. Non-Codable Approach Procedures. Certain part 97 nonprecision instrument approaches as well as some military and special procedures may present an unresolvable coding situation relating to database or equipment interface constraints. An approach may be determined to be not codable or not flyable by the regulatory agency having jurisdiction (FAA), by the database coding agency, or by the manufacturer of the navigation equipment. In addition, some procedures may, in the opinion of the

FAA, present a potential safety hazard to normal piloting techniques using GPS equipment. These procedures will not be included in navigation

databases. Approach procedures that are omitted from the database can not be legally flown using GPS navigation equipment.

c. Waypoints. As a minimum, the GPS Approach Overlay Program requires that the databases contain waypoints representing the IAF, FAF, MAP, and the missed approach holding point for each VOR, VOR/DME, NDB, NDB/DME, TACAN, and RNAV nonprecision instrument approach procedure. Intermediate Fixes (IF's) and all named fixes are also included. All waypoints are displayed in the same sequence as they are presented on the published nonprecision instrument approach procedure charts.

Note: User modification or entry of data associated with published instrument approach procedures is not possible, and not authorized.

(1) Waypoint data utilized in nonprecision instrument approach procedures is stored by name or ident, and latitude and longitude. The waypoints are not designated in terms of bearing (or radial) and distance to/from a reference location.

(2) Waypoints that define the MAP and Missed Approach Holding Point (MAHWP) are always coded as "fly over." This type of waypoint requires the aircraft to pass directly over it.

(3) When turn anticipation is expected at an IAF or other waypoint the waypoint is coded as "fly by."

d. Waypoint Names Coded in the Navigation Database. Flying a part 97 or military nonprecision instrument approach procedure using GPS equipment should be transparent to air traffic control. Therefore, if a pilot has a clearance for the VOR/DME to runway 35, the same track is flown whether using GPS equipment or VOR and DME equipment. Therefore, waypoints coded in the navigation database reflect exactly those names appearing on the instrument approach procedure. For example, if an IAF or other fix is assigned a pronounceable five-letter alpha character name, it will be the same name coded in the database, the name which will appear on the avionics display, the name appearing on a chart, and the name verbally used by ATC. If no five character name is published for the approach waypoint or fix, it will normally be coded with a database identifier. A pilot must associate the coded name appearing on the display with the position shown on the chart. However, these coded names may not be known or used by ATC.

(1) Initial Approach Waypoint.

(a) If the IAF is a named waypoint or fix, then the same name is used for the IAF waypoint in the database. If the IAF is a NAVAID, then the IAF waypoint is coded with the NAVAID identifier.

(b) A database identifier is provided for an unnamed IAF.

(c) When an IAF is the beginning of a DME arc segment, the IAF is often unnamed, but is marked by a radial intersecting the arc. In these cases, the unnamed IAF waypoint is coded in the database to represent the beginning of the DME arc. An example of one method of identifying the beginning of the arc is shown in the Lake Charles, LA chart example in Appendix 3.

(2) Turnings points in the Initial Segment**.** An initial segment may incorporate a named or unnamed turn point to intercept a course.

(a) In some cases, a waypoint may be established at a turn point where a dead reckoning heading intersects the course. This waypoint is coded into the waypoint sequence for GPS navigation, but may not be named on a chart.

(b) A turn point may be defined by the intersection of two NAVAID radials or bearings. In this case, a waypoint name appears in the sequence.

(3) Intermediate Waypoint**.** If the IF is a named waypoint or fix, then the same name is used for the IF waypoint in the database. If the IF is a NAVAID, the IF waypoint is coded with the NAVAID identifier. An unnamed IF is assigned a database identifier.

(4) Final Approach Waypoint.

(a) Procedures With a Final Approach Fix (FAF). If the FAF is a named waypoint or fix, the same name is used for the FAF waypoint in the database sequence. If the FAF is a NAVAID, the waypoint is coded with the NAVAID identifier in the waypoint sequence. An unnamed FAF, such as a DME fix, is coded with a descriptive FAF waypoint related to the NAVAID providing final approach course guidance. It also appears in the waypoint sequence.

(b) Procedures Without a Final Approach Fix**.** Procedures without a FAF and without a stepdown fix have a Sensor FAF waypoint coded in the database at least 4 NM along track distance (ATD) to the MAP waypoint. The MAP, in this case, is always located at the NAVAID facility. A Sensor FAF is a final approach waypoint created and added to the database sequence of waypoints to support GPS navigation of an FAA published, no-FAF, nonprecision instrument approach procedure. The coded name or Sensor FAF appears in the waypoint sequence. If a stepdown fix exists on the published procedure and it is greater than 2 NM to the MAP, the stepdown fix is coded in the database as the Sensor FAF waypoint for the waypoint sequence. If a stepdown fix distance is 2 NM or less to the MAP, a Sensor FAF waypoint is coded at least 4 NM to the MAP.

(5) Missed Approach Waypoint**.** When a missed approach point is located at the NAVAID, the MAP waypoint is coded in the sequence at the NAVAID position using the NAVAID identifier. When the missed approach is initiated near the runway threshold (timed approach) or at a specified DME distance from a NAVAID, a MAP waypoint is created and coded in the database (see approach charts in Appendix 3).

(6) Missed Approach Holding Points**.** Missed approach holding points are normally at a NAVAID or named fix. Therefore, the NAVAID identifier or the fix name is coded in the database as the missed approach holding waypoint and appears in the waypoint sequence.

(7) Waypoints and Fixes not Coded for the GPS Approach Overlay Program. A Visual Descent Point (VDP) is a fix appearing on some published nonprecision approach procedures that is not included in the sequence of waypoints. Pilots are expected to use normal piloting techniques for beginning the visual descent. In addition, unnamed stepdown fixes in the final approach segment will not be coded in the waypoint sequence unless the stepdown fix is used as a Sensor FAF on a no-FAF procedure.

e. Approach Selection Process/Menu Sluing. Pilots normally retrieve instrument approach procedures from the database through a menu selection process. An example of a menu selection is included in the Pilot Operations/Procedures section. No manual waypoint loading will be required or allowed, although some pilot action is required during certain segments of the approach.

> **Note: This process may vary from one avionics manufacturer to another; therefore, pilots must be thoroughly familiar with the FAA Approved Flight Manual or Flight Manual supplement.**

f. Waypoint Sequence. The sequence of waypoints in the database and those displayed by the equipment will consist of, as a minimum, waypoints representing the selected IAF and its associated IFs (when applicable), FAF, MAP, and the MAHWP.

g. Relationship of Avionics Displayed Waypoints to Charted Data. The GPS Approach Overlay Program waypoints contained in the database represent the waypoints, fixes, NAVAIDs, and other points portrayed on a published approach procedure beginning at the initial approach fix. Certain unnamed points and fixes appearing on a chart are assigned a database identifier. Although there currently is no requirement to provide these database identifiers, most charting agencies are publishing them at their discretion. The NOS will begin publishing these fixes on overlay approach charts in early 1999.

> **Note: Database identifiers should not be used for pilot/controller communications or on flight plans.**

h. Differences Between Displayed and Charted Navigation Information. There may be slight differences between the navigation information portrayed on the chart and the GPS navigation display. Course differences will occur due to an equipment manufacturer’s application of magnetic variation. Distance differences will occur due to the mismatch between GPS (along track distance) ATD values and the DME values published on underlying procedures.

SECTION 5. PILOT OPERATIONS/PROCEDURES.

1. APPLICABILITY. The guidance provided in this AC applies to instrument rated pilots using GPS and operating under part 91. Pilots conducting GPS IFR operations under parts 121, 129, and 135 should meet the appropriate provisions of their approved operations specifications.

2. GENERAL. All GPS IFR operations should be conducted in accordance with the FAA Approved Flight Manual (AFM) or Flight Manual Supplement. Prior to an IFR flight using GPS, the pilot should ensure that the GPS equipment and the installation are approved and certified for the intended IFR operation. The equipment should be operated in accordance with the provisions of the applicable AFM. All pilots must be thoroughly familiar with the GPS equipment installed in the aircraft and its limitations.

a. Position Orientation. As with most RNAV systems, pilots should pay particular attention to position orientation while using GPS. Distance and track information are provided to the next active waypoint, not to a fixed navigation aid. Receivers may sequence when the pilot is not flying along an active route, such as when being vectored or deviating for weather, due to the proximity to another waypoint in the route. This can be prevented by placing the receiver in the nonsequencing mode. When the receiver is in the nonsequencing mode, bearing and distance are provided to the selected waypoint and the receiver will not sequence to the next waypoint in the route until placed back in the auto-sequence mode or the pilot selects a different waypoint. On overlay approaches, the pilot may have to compute the along track distance to stepdown fixes and other points due to the receiver showing along track distance to the next waypoint rather than DME to the VOR or ILS ground station.

b. Conventional Versus GPS Navigation Data. There may be slight differences between the heading information portrayed on navigational charts and the GPS navigation display when flying an overlay approach or along an airway. All magnetic tracks defined by a VOR radial are determined by the application of magnetic variation at the VOR; however, GPS operations may use an algorithm to apply the magnetic variation at the current position, which may produce small differences in the displayed course. Both operations should produce the same desired ground track. Due to the use of great circle courses, and the variations in magnetic variation, the bearing to the next waypoint and the course from the last waypoint (if available) may not be exactly 180 degrees apart when long distances are involved. Variations in distances will occur since GPS distance-to-waypoint values are along track (straight-line) distances (ATD) computed to the next waypoint and the DME values published on underlying procedures are slant range distances measured to the station. This difference increases with aircraft altitude and proximity to the NAVAID.

c. GPS NOTAM's/Aeronautical Information. GPS satellite outages are issued as GPS NOTAM's both domestically and internationally. However, the effect of an outage on the intended operation cannot be determined unless the pilot has a RAIM availability prediction program which allows excluding a satellite which is predicted to be out of service based on the NOTAM information.

(1) Civilian pilots may obtain GPS RAIM availability information for nonprecision approach procedures by specifically requesting GPS aeronautical information from an Automated Flight Service

Station during preflight briefings. GPS RAIM aeronautical information can be obtained for a period of 3 hours (ETA hour and 1 hour before to 1 hour after the ETA hour) or a 24 hour time frame at a particular airport. FAA briefers will provide RAIM information for a period of 1 hour before to 1 hour after the ETA, unless a specific time frame is requested by the pilot. If flying a published GPS departure, a RAIM prediction should also be requested for the departure airport.

(2) The military provides airfield specific GPS RAIM NOTAM's for nonprecision approach procedures at military airfields. The RAIM outages are issued as M-series NOTAM's and may be obtained for up to 24 hours from the time of request.

d. Receiver Autonomous Integrity Monitoring (RAIM). RAIM outages may occur due to an insufficient number of satellites or due to unsuitable satellite geometry which causes the error in the position solution to become too large. Loss of satellite reception and RAIM warnings may occur due to aircraft dynamics (changes in pitch or bank angle). Antenna location on the aircraft, satellite position relative to the horizon, and aircraft attitude may affect reception of one or more satellites. Since the relative positions of the satellites are constantly changing, prior experience with the airport does not guarantee reception at all times, and RAIM availability should always be checked.

(1) If RAIM is not available, another type of navigation and approach system must be used, another destination selected, or the trip delayed until RAIM is predicted to be available on arrival.

(2) On longer flights, pilots should consider rechecking the RAIM prediction for the destination during the flight. This may provide early indications that an unscheduled satellite outage has occurred since takeoff.

3. PREFLIGHT. The pilot should follow the specific start-up and self-test procedures for the GPS receiver as outlined in the FAA AFM or Flight Manual Supplement.

a. Prior to any GPS IFR operation, the pilot should review the appropriate NOTAM's. NOTAM's will be issued to announce outages for specific GPS satellite vehicles, by pseudo random noise (PRN) number and satellite vehicle number (SVN). GPS NOTAM's are issued under the identifier "GPS". Pilots may obtain GPS NOTAM information by request to the FSS briefer or by requesting NOTAM's, using the identifier "GPS", through the Direct User Access Terminal System (DUATS). Pilots should review the NOTAM's for the underlying approach procedure. When executing an Overlay Approach which requires operative ground NAVAID(s), one without the "or GPS" nomenclature in the title of the approach, pilots should ensure the ground-based facilities upon which the approach is based are operational. If an approach is not authorized due to an inoperative navigation facility, the associated GPS approach is not authorized.

b. Aircraft that are navigating by GPS are considered to be RNAV-equipped aircraft and the appropriate equipment suffix should be included in the ATC flight plan.

Most GPS equipment would file as a /G. Users should consult the latest edition of the Airmen's Information Manual (AIM) for the proper equipment suffix. If the GPS avionics becomes inoperative, the pilot should advise ATC and amend the equipment suffix.

4. DEPARTURES AND INSTRUMENT DEPARTURE PROCEDURES (DP's).

a. The GPS receiver must be set to terminal (±1 NM) course deviation indicator (CDI) sensitivity (or confirmed that the receiver has automatically set it) and the navigation routes must be contained in the data base in order to fly published IFR charted departures and DP's. For FMS equipped aircraft without the capability of manually setting the CDI the departure must be flown with a flight director. Terminal RAIM should be automatically provided by the receiver.

> **Note: Terminal RAIM for departure may not be available unless the waypoints are part of the active flight plan rather than proceeding direct to the first destination.**

b. Certain segments of a DP may require some manual intervention by the pilot, especially when radar vectored to a course or required to intercept a specific course to a waypoint. The data base may not contain all of the transitions or departures from all runways and some GPS receivers do not contain DP's in the data base. Helicopter-only GPS departure procedures are to be flown at 70 knots or less since turning areas and segment lengths are based on this speed.

5. EN ROUTE DOMESTIC OPERATIONS. Domestic en route operations are defined as that phase of flight between departure and arrival terminal phases, with departure and arrival points within the U.S. NAS. Terminal area operations include those flight phases conducted on charted Instrument Departure Procedures (DP's), on Standard Terminal Arrival Routes (STAR's), or during other flight operations between the last en route fix/waypoint and an initial approach fix/waypoint. The following criteria applies:

a. Navigation equipment should be installed and operational to receive the intended ground-based facilities which define the route to be flown to the destination and any required alternate.

b. Ground-based facilities which define these routes must also be operational.

c. Aircraft should be equipped with an approved and operational alternate means of navigation appropriate to the route being flown. This navigation equipment must be operational, but it does not have to be actively monitored unless the RAIM capability of the system fails. The purpose of these backup systems is to ensure that the aircraft can continue to the destination if something unforeseen occurs to the avionics or GPS constellation.

6. TERMINAL OPERATIONS. GPS equipment may be used to fly all codable nonprecision instrument approach procedures, except localizer (LOC), localizer directional aid (LDA), and simplified directional facility (SDF) approach procedures. Any required alternate airport should have an approved instrument approach procedure (other than GPS or LORAN-C) which is anticipated to be operational at the estimated time of arrival.

a. GPS Approach Criteria. For the Approach Overlay Program, civil aircraft are not authorized to use GPS to fly any segment of any instrument approach under IFR weather conditions unless the following criteria are met:

(1) The GPS avionics used to fly any nonprecision instrument approach must be certified to TSO-C129 or equivalent criteria. The installation in the aircraft should be in accordance with AC 20-138 and the provisions of the applicable Approved Flight Manual (AFM) or Flight Manual supplement should be met.

(2) The airborne navigation database should contain all waypoints for the published nonprecision approaches to be flown. The use of TSO-C129 GPS equipment is not authorized for LOC, LDA, and SDF approaches.

(3) The approach cannot be flown unless that instrument approach is retrievable from the avionics database. Some approach procedures are not included in the database due to safety reasons or non-codability. It is the responsibility of the pilot to determine if the intended approach procedure is in the database.

(4) The GPS avionics should store all waypoints depicted in the approach to be flown, and present them in the same as the published nonprecision instrument approach procedure chart.

(5) Approaches must be flown in accordance with the FAA AFM or Flight Manual Supplement and the procedure depicted on the appropriate instrument approach chart.

(6) Any required alternate airport should have an approved instrument approach procedure, other than GPS or LORAN-C, which is anticipated to be operational at the estimated arrival time. The aircraft should have the appropriate avionics installed and operational to receive the navigational aids. The pilot is responsible for checking NOTAM's to determine the operational status of the alternate airport navigational aids.

(7) The general approval to use GPS to fly overlay instrument approaches is initially limited to the U.S. National Airspace System (NAS). GPS instrument approach operations outside the United States also should be authorized by the appropriate sovereign authority.

b. RAIM Considerations. The pilot must select the appropriate airport(s), runway/approach procedure, and initial approach fix on the aircraft's GPS receiver to determine RAIM integrity for that approach. Air Traffic Control specialists are not provided any information about the operational integrity of the system. This is especially important when the pilot has been "Cleared for the Approach." Procedures should be established by the pilot in the event that GPS navigation outages are predicted or occur. In these situations, the pilot should rely on other approved equipment, delay departure, or cancel the flight.

(1) **If a RAIM failure/status annunciation occurs prior to the final approach waypoint (FAWP), the approach should not be completed since GPS may no longer provide the required accuracy**. The receiver performs a RAIM prediction by 2 NM prior to the

FAWP to ensure that RAIM is available at the FAWP as a condition for entering the approach mode. **The pilot should ensure that the receiver has sequenced from "Armed" to "Approach" prior to the FAWP** (normally occurs 2 NM prior). Failure to sequence may be an indication of the detection of a satellite anomaly, failure to arm the receiver (if required), or other problems which preclude completing the approach.

(2) If the receiver does not sequence into the approach mode or a RAIM failure/status annunciation occurs prior to the FAWP, the pilot should not descend to MDA, but should proceed to the missed approach waypoint (MAWP) via the FAWP, perform a missed approach, and contact ATC as soon as practical. Refer to the receiver operating manual for specific indications and instructions associated with loss of RAIM prior to the FAF.

(3) If a RAIM failure occurs after the FAWP, the receiver is allowed to continue operating without an annunciation for up to 5 minutes to allow completion of the approach (see receiver operating manual). **If the RAIM flag/status annunciation appears after the FAWP, the missed approach should be executed immediately.**

c. Flying GPS Approaches. Usually, flying a GPS Overlay nonprecision instrument approach procedure is identical to a traditional approach. The differences include the navigational information displayed on the GPS equipment and the terminology used to describe some of the features. Flying the GPS stand alone approach is normally point to point navigation and independent of any ground based NAVAIDs. Appendix 3 contains sample charts with a brief explanation of how pilot operations are affected by each of these types of GPS approach operations. Proper approach planning and a sound knowledge of the onboard GPS avionics' capabilities and limitations are critical to a safe operation. Because GPS receivers vary widely in their respective presentations and operation, the following guidance is generic in nature but should prove valuable for pilots who choose to fly GPS approaches.

(1) Determining which area of the TAA the aircraft will enter when flying a "T" with a TAA must be accomplished using the bearing and distance to the IF (IAF). This is most critical when entering the TAA in the vicinity of the extended runway centerline and determining whether you will be entering the right or left base area. Once inside the TAA, all sectors and stepdowns are based on the bearing and distance to the IAF for that area, which the aircraft should be proceeding direct to at that time, unless on vectors. (See Figure 2-1 and Figure 2-2.)

(2) Pilots should fly the full approach from an Initial Approach Waypoint (IAWP) or feeder fix unless specifically cleared otherwise. Randomly joining an approach at an intermediate fix does not assure terrain clearance.

(3) When an approach has been loaded in the flight plan, GPS receivers, which require manual arming, will give an "arm" annunciation 30 NM straight line distance from the airport/heliport reference point. Pilots should arm the approach mode at this time, if it has not already been armed (some receivers arm automatically). Without arming, the receiver will not change from en route CDI and RAIM sensitivity of ±5 NM either side of centerline to ±1 NM terminal sensitivity. Where the IAWP

is inside this 30 mile point, a CDI sensitivity change will occur once the approach mode is armed and the aircraft is inside 30 NM. Where the IAWP is beyond 30 NM from the airport/heliport reference point, CDI sensitivity may not change until the aircraft is within 30 miles of the airport/heliport reference point even if the approach is armed earlier. Obstacle clearance is predicated on the receiver being in terminal (±1 NM) CDI sensitivity and RAIM at the IAWP or within 30 NM of the airport/heliport reference point, whichever occurs last.

(4) The pilot must be aware of what bank angle/turn rate the particular receiver uses to compute turn anticipation, and whether wind and airspeed are included in the receiver's calculations. This information should be in the receiver operating manual. Over or under banking the turn onto the final approach course may significantly delay getting on course and may result in high descent rates to achieve the next segment altitude.

(5) When within 2 NM of the FAWP with the approach mode armed, the approach mode will switch to active, which results in RAIM changing to approach sensitivity and a change in CDI sensitivity. Beginning 2 NM prior to the FAWP, the full scale CDI sensitivity will smoothly change from ±1 NM, to ±0.3 NM at the FAWP. As sensitivity changes from ±1 NM to ±0.3 NM approaching the FAWP, with the CDI not centered, the corresponding increase in CDI displacement may give the impression that the aircraft is moving further away from the intended course even though it is on an acceptable intercept heading. Referencing the digital track displacement information (cross track error), if it is available in the approach mode, may help the pilot remain position oriented in this situation. Being established on the final approach course prior to the beginning of the sensitivity change at 2 NM will help prevent problems in interpreting the CDI display during ramp down. Therefore, requesting or accepting vectors which will cause the aircraft to intercept the final approach course within 2 NM of the FAWP is not recommended.

(6) When receiving vectors to final, most receiver operating manuals suggest placing the receiver in the nonsequencing mode on the FAWP and manually setting the course. This provides an extended final approach course in cases where the aircraft is vectored onto the final approach course outside of any existing segment which is aligned with the runway. Assigned altitudes must be maintained until established on a published segment of the approach. Required altitudes at waypoints outside the FAWP or stepdown fixes must be considered. Calculating the distance to the FAWP may be required in order to descend at the proper location.

(7) Overriding an automatically selected sensitivity during an approach will cancel the approach mode annunciation. If the approach mode is not armed by 2 NM prior to the FAWP, the approach mode will not become active at 2 NM prior to the FAWP, and the equipment will flag. In these conditions, the RAIM and CDI sensitivity will not ramp down, and the pilot should not descend to MDA, but fly to the MAWP and execute a missed approach. The approach active annunciator and/or the receiver should be checked to ensure the approach mode is active prior to the FAWP.

(8) Do not attempt to fly an approach unless the procedure is contained in the current GPS data base. Flying point to point on the approach does not assure compliance with the

published approach procedure. The proper RAIM sensitivity will not be available and the CDI sensitivity will not automatically change to ±0.3 NM. Manually setting CDI sensitivity does not automatically change the RAIM sensitivity on some receivers. Some existing nonprecision approach procedures cannot be coded for use with GPS and will not be available as overlays.

(9) Pilots should pay particular attention to the exact operation of their GPS receivers for performing holding patterns and in the case of overlay approaches, operations such as procedure turns. These procedures may require manual intervention by the pilot to stop the sequencing of waypoints by the receiver and to resume automatic GPS navigation sequencing once the maneuver is complete. The same waypoint may appear in the route of flight more than once (e.g., IAWP, FAWP, MAHWP on a procedure turn). Care must be exercised to ensure that the receiver is sequenced to the appropriate waypoint for the segment of the procedure being flown, especially if one or more fly-overs are skipped (e.g., FAWP rather than IAWP if the procedure turn is not flown). The pilot may have to sequence past one or more fly-overs of the same waypoint in order to start GPS automatic sequencing at the proper place in the sequence of waypoints.

(10) Incorrect inputs into the GPS receiver are especially critical during approaches. In some cases, an incorrect entry can cause the receiver to leave the approach mode.

(11) A fix on an overlay approach identified by a DME fix will not be in the waypoint sequence on the GPS receiver unless there is a published name assigned to it. When a name is assigned, the along track to the waypoint may be zero rather than the DME stated on the approach chart. The pilot should be alert for this on any overlay procedure where the original approach used DME.

(12) If a visual descent point (VDP) is published, it will not be included in the sequence of waypoints. Pilots are expected to use normal piloting techniques for beginning the visual descent. In addition, unnamed step-down fixes in the final approach segment will not be coded in the waypoint sequence and must be identified using ATD.

(13) Straight line (TO-TO) flight from waypoint to waypoint, as sequenced in the database, does not assure compliance with the published approach procedure. Should differences between the approach chart and database arise, the published approach chart, supplemented by NOTAM's, holds precedence.

d. Initial Approach Segments. The following are some of the unique characteristics a pilot should be aware of during the initial approach segment of a nonprecision GPS approach.

(1) Arc Procedures. Arc procedures will only be encountered with overlay approaches. The method for navigating on arcs may vary with the manufacturer and pilots should use the procedures specified in the applicable AFM. It is not uncommon for an aircraft to be vectored onto the arc by ATC at a point other than the IAF for the arc. In these cases, the pilot should manually sequence the waypoints to the arc segment of the approach.

(2) Course Reversal Procedure**.** When performing a course reversal, such as a procedure turn or holding pattern in lieu of a procedure turn, the GPS equipment provides the capability for the pilot to change from the automatic waypoint sequencing to manual. The course reversal is flown using normal piloting techniques. The reversal and the return to automatic sequencing should be completed when established inbound on the final approach course to, but outside of the active waypoint.

> **Note: The method or procedure used to switch the equipment from automatic sequencing to manual may vary between manufacturers. Pilots should use the procedure specified in the applicable AFM.**

(3) Turn Points in the Initial Segment. In some cases, a turn point is incorporated in the initial approach segment.

> **Note: It is important to recognize that the turn point may be either a named or coded waypoint.**

e. Final Approach Segment. The following are some of the unique characteristics a pilot should be aware of during the final approach segment of a nonprecision GPS approach:

(1) Final Approach Fix (FAF) - Overlay Approach. In the Approach Overlay Program, the GPS equipment may display a FAF waypoint not depicted on the approach chart. Procedures without a FAF and without a stepdown fix have a sensor FAF waypoint coded in the database. This sensor FAF waypoint is at least 4 NM to the MAP waypoint. In this case, the MAP waypoint is always located at the NAVAID facility. If a stepdown fix exists on the published procedure that is greater than 2 NM to the MAP, the stepdown fix becomes the sensor FAF waypoint. If a stepdown fix is 2 NM or less to the MAP, a sensor FAF waypoint is established 4 NM to the MAP. The sensor FAF is necessary to transition the display sensitivity on the GPS equipment from terminal to approach sensitivity. During communications with ATC, the pilot should make position reports based on charted positions, not the display on the GPS equipment, since the controller does not have access to this information. Examples of these situations are shown in the sample charts in Appendix 3.

(2) Final Approach Waypoint - GPS Stand Alone Approach. The final approach waypoint for a GPS stand alone approach will be a standard named waypoint normally located 5 NM from the runway end.

(3) Course Sensitivity. The Course Deviation Indicator (CDI) sensitivity related to GPS equipment varies with the mode of operation. In the en route phase, prior to the execution of the instrument approach, the display sensitivity full scale deflection is 5 NM either side of centerline.

(a) Upon activation of the terminal mode, the display sensitivity transitions from a full scale deflection of 5 NM to 1 NM either side of centerline.

(b) At a distance of 2 NM inbound to the FAF waypoint, the display sensitivity begins to transition to a full scale deflection of 0.3 NM either side of centerline. Some GPS avionics may provide an angular display between the FAF and MAP that approximates the course sensitivity of the localizer portion of an ILS.

(c) When navigation to the missed approach is activated, the display sensitivity transitions to provide a full scale deflection of one nautical mile either side of centerline.

(4) Stepdown Fixes. A stepdown fix is flown in the same manner as a ground-based approach. Stepdown fixes on overlay approaches will not be identified with a waypoint unless it is named by the FAA. An unnamed stepdown fix will not appear in the database sequence of waypoints. Pilots should be aware that the distance readout in the GPS display equates to the *distance-to-go to the active waypoint*. If the stepdown fix has not been assigned a waypoint name in the database (for overlay approach stepdown fixes), the distance-to-go readout may not correspond to the DME distance of the stepdown fix shown on the published approach chart. The pilot should monitor the along track distance (ATD) to the MAP to identify the stepdown fix. For stand alone GPS procedures, any required stepdown fixes prior to the missed approach waypoint will be identified by along track distances.

Note: An approach fix identified by a DME will not be displayed on the GPS receiver unless there is a published name assigned to the DME fix. If the fix is not assigned a waypoint name, the distance-to-go ATD displayed on the GPS receiver may not agree with the approach chart DME reference distance.

f. GPS Missed Approaches. A GPS missed approach requires pilot action to sequence the receiver past the MAWP to the missed approach portion of the procedure. The pilot must be thoroughly familiar with the activation procedure for the particular GPS receiver installed in the aircraft and must **initiate appropriate action after the MAWP.** Activating the missed approach prior to the MAWP will cause CDI sensitivity to immediately change to terminal (±1 NM) sensitivity and the receiver will continue to navigate to the MAWP. The receiver will not sequence past the MAWP. Turns should not begin prior to the MAWP. If the missed approach is not activated, the GPS receiver will display an extension of the inbound final approach course and the ATD will increase from the MAWP until it is manually sequenced after crossing the MAWP.

(1) Missed approach routings in which the first track is via a course rather than direct to the next waypoint **require additional action by the pilot** to set the course. Being familiar with all of the inputs required is especially critical during this phase of flight.

(2) The MAP waypoint on an overlay approach may be located at the runway threshold, the underlying facility, or at a specified distance from the runway or facility. There may be a difference between the along track countdown to the waypoint in the GPS equipment and the DME distance from

a facility shown on the chart. Pilots need to take into account any differences when interpreting the distance shown in the GPS display against the charted values.

(3) After passing the missed approach point, the GPS equipment will not automatically sequence to the missed approach holding waypoint. When initiating a missed approach the pilot, upon passing the MAP, should manually sequence the GPS equipment to the next active waypoint. This may not necessarily be a missed approach holding waypoint, but may be a turn waypoint en route to the missed approach holding waypoint. The missed approach should be flown as charted using the same piloting techniques as a traditional missed approach.

g. Selected Pilot Operations. Using GPS to conduct instrument procedures requires that a pilot has a thorough knowledge of the specific avionics installed on the aircraft and knowledge of the procedural sequence involved with flying a specific approach. Appendix 3 contains specific examples of GPS approaches and the pilot procedures that should be followed in order to successfully complete them.

APPENDIX 1 — DEFINITIONS

Active Waypoint	The waypoint to/from which the navigational guidance is being provided.
Along Track Distance (ATD) Fix	A distance in NM to the active waypoint along the specified track. An ATD fix will not be used where a course change is made.
Class II Navigation	Any en route flight operation or portion of an en route operation (irrespective of the means of navigation) which takes place outside (beyond) the designated Operational Service Volume of the International Civil Aviation Organization (ICAO) standard airway navigation facilities (VOR, VOR/DME, NDB).
Course Set	Guidance set from information provided by area navigation (RNAV) equipment that assists the pilot in navigating to or from an active waypoint on a heading/bearing.
Data Agency	An agency, public or private, other than a publisher of government source documents, who compiles official document information into charts or electronic formats for cockpit use.
Dead Reckoning (DR)	The navigation of an airplane solely by means of computations based on airspeed, course, heading, wind direction and speed, ground speed, and elapsed time.
Direct To	A method used with RNAV equipment to provide the necessary course from present position directly to a selected waypoint. This is not the *course* from waypoint to waypoint.
En Route Domestic	The phase of flight between departure and arrival terminal phases, with departure and/or arrival points within the U.S. National Airspace System (NAS).
En Route Oceanic	The phase of flight between the departure and arrival terminal phases, with an extended flight route over the high seas.
En Route Operations	The phase of navigation covering operations between departure and arrival terminal phases. The en route phase of navigation has two subcategories: en route domestic and en route oceanic.
Fault Detection and Exclusion (FDE)	Equipment capability to detect a satellite failure which effects navigation and the subsequent automatic exclusion of that satellite from the navigation solution.
Fly-By Waypoint	A waypoint that permits turn anticipation and does not require the aircraft to pass directly over it. Obstacle clearance is based on turning prior to the waypoint.
Fly-Over Waypoint	A waypoint that requires the aircraft to pass directly over it.

Geodetic Datum	The numerical or geometrical quantity or set of such quantities (mathematical model) which serves as a reference for computing other quantities in a specific geographic region such as the latitude and longitude of a point.
Global Navigation Satellite Systems (GNSS)	An "umbrella" term adopted by ICAO to encompass any independent satellite navigation system used by a pilot to perform onboard position determinations from the satellite data.
Global Positioning System (GPS)	A U.S. space-based positioning, velocity, and time system composed of space, control, and user elements. The space element, when fully operational, will be composed of 24 satellites in six orbital planes. The control element consists of five monitor stations, three ground antennas and a master control station. The user element consists of antennas and receiver-processors that provide positioning, velocity, and precise timing to the user.
Instrument Approach Waypoints	Geographical positions, specified in latitude/longitude used in defining GPS instrument approach procedures, including the initial approach waypoint, the intermediate waypoint, the final approach waypoint, the missed approach waypoint, and the missed approach holding waypoint.
Integrity	The probability that a system will provide accurate navigation as specified or timely warnings to users when GPS data should not be used for navigation.
National Airspace System (NAS)	The common network of U.S. airspace; air navigation facilities, equipment and services, airport or landing areas; aeronautical charts, information and services; rules, regulations and procedures, technical information, and manpower and materiel. Included are system components shared jointly with the military.
Nonprecision Approach Operations	Those flight phases conducted on charted Standard Instrument Approach Procedures (SIAP's) commencing at the initial approach fix and concluding at the missed approach point or the missed approach holding point, as appropriate.
Oceanic Airspace	Airspace over the oceans of the world, considered international airspace, where oceanic separation and procedures per ICAO are applied. Responsibility for the provisions of air traffic control service in this airspace is delegated to various countries, based generally upon geographic proximity and the availability of the required resources.

Primary Means Navigation System	A navigation system approved for a given operation or phase of flight that must meet accuracy and integrity requirements, but need not meet full availability and continuity of service requirements. Safety is achieved by limiting flights to specific time periods and through appropriate procedural restrictions. Note - There is no requirement to have a sole-means navigation system on board to support a primary-means system.
Pseudo-Range	The determination of position, or the obtaining of information relating to position, for the purposes of navigation by means of the propagation properties of radio waves. The distance from the user to a satellite plus an unknown user clock offset distance. With four satellite signals it is possible to compute position and clock offset distance.
Receiver Autonomous Integrity Monitoring (RAIM)	A technique whereby a civil GPS receiver/processor determines the integrity of the GPS navigation signals using only GPS signals or GPS signals augmented with altitude. This determination is achieved by a consistency check among redundant pseudo-range measurements. At least one satellite in addition to those required for navigation must be in view for the receiver to perform the RAIM function.
Secondary Sensor	Any input from other aircraft systems that may be used to derive navigation information.
Selective Availability (SA)	A method by which the DOD can artificially create a significant time and positioning error in the satellites. This feature is designed to deny an enemy the use of precise GPS positioning data.
Sensor FAF	A final approach waypoint created and added to the database sequence of waypoints to support GPS navigation of an FAA published, no-FAF, nonprecision instrument approach procedure.
Supplemental Means Navigation System	A navigation system that must be used in conjunction with a sole-means navigation system. Approval for supplemental-means for a given phase of flight requires that a sole-means navigation system for that phase of flight must be on board. Amongst the navigation system performance requirements for a given operation or phase of flight, a supplemental-means navigation system must meet the accuracy and integrity requirements for that operation or phase of flight; there is no requirement to meet availability and continuity requirements. Note - Operationally, while accuracy and integrity requirements are being met, a supplemental-means system can be used without any cross-check with the sole-means system. Any navigation system approved for supplemental-means could involve one (stand-alone installation) or several sensors, possibly of different types (multi-sensor installation).
Terminal Area Operations	Those flight phases conducted on charted Instrument Departure Procedures (DP's), on Standard Terminal Arrival Routes

	(STAR's), or other flight operations between the last en route fix/waypoint and the initial approach fix/waypoint.
TO-FROM Navigation	RNAV equipment in which the desired path over the ground is defined as a specific (input quantity) course emanating either to or from a particular waypoint. The equipment functions like a conventional VOR receiver where the course deviation indicator (CDI) needle and the "to/from" indicator responds to movement of the omni bearing selector (OBS). In this equipment, the aircraft may fly either TO or FROM any single designated waypoint.
TO-TO Navigation	RNAV equipment in which a path is computed that connects two waypoints. In this equipment, two waypoints must always be available, and the aircraft is usually flying between the two waypoints and TO the active waypoint. In this equipment the CDI needle functions like its tracking a localizer signal; that is movement of the OBS has no effect on the CDI needle or the "to/from" indicator.
Turn Anticipation	The capability of RNAV systems to determine the point along a course, prior to a turn waypoint, where a turn should be initiated to provide a smooth path to intercept the succeeding course within the protected airspace, and to enunciate the information to the pilot.
User-selectable Navigation Database	A navigation database having user-defined contents accessible by the pilot and/or the navigation computer during aircraft operations in support of navigation needs. This database is stored electronically and is typically updated at regular intervals, such as the Aeronautical Information Regulation and Control (AIRAC) 28-day cycle. It does not include data that can be entered manually by the pilot or operator.
Waypoint (WP)	A predetermined geographical position used for route definition and/or progress reporting purposes that is defined by latitude/longitude.
World Geodetic System (WGS)	A consistent set of parameters describing the size and shape of the earth, the positions of a network of points with respect to the center of mass of the earth, transformations from major geodetic datums, and the potential of the earth (usually in terms of harmonic coefficients).

APPENDIX 2 - GPS PILOT TRAINING

1. GENERAL. Pilots should practice Global Positioning System (GPS) approaches under visual meteorological conditions (VMC) until thoroughly proficient with all aspects of their equipment (receiver and installation) prior to attempting flight by Instrument Flight Rules (IFR) in instrument meteorological conditions (IMC). Many GPS receivers provide a simulation mode which can be used to become familiar with receiver operations prior to actual flight operations. Some of the areas which the pilot should practice are:

a. Utilizing the receiver autonomous integrity monitoring (RAIM) prediction function;

b. Proceeding direct to a waypoint in and not in the flight plan;

c. Inserting an instrument departure procedure (DP) into the flight plan, including setting terminal course deviation indicator (CDI) sensitivity, if required, and the conditions under which terminal RAIM is available for departure (some receivers are not DP or standard terminal arrival area (STAR) capable);

d. Inserting the destination airport in a flight plan;

e. Determining the correct initial approach fix (IAF) to proceed to when entering a terminal arrival area (TAA) and determining the correct altitudes within a TAA;

f. Executing overlay approaches (especially "no-FAF" procedure turns and arcs);

g. Changing to another approach after selecting an approach;

h. Executing "direct" missed approaches where the route is direct to the first waypoint after the missed approach waypoint (MAWP);

i. Executing "routed" missed approaches where the route is not direct to a waypoint from the MAWP, particularly where a course must be manually inserted and flown. This procedure may vary with installation of the receiver;

j. Entering, flying and exiting holding patterns "manually" with a receiver that usually does this procedure automatically (e.g. non-charted holding, holding following a procedure turn, and holding with a second waypoint in the holding pattern);

k. Flying a "route" from a holding pattern to another waypoint;

l. Executing an approach with radar vectors to the final segment;

m. Indication of the actions required for RAIM failure both before and after the final approach waypoint (FAWP);

n. Programming a radial and distance from a VOR (often used in departure instructions);

o. Recovering from sequencing past a waypoint at which holding was intended.

APPENDIX 3 - PILOT SELECTED PRACTICES

1. GENERAL. This appendix is intended to provide examples of different kinds of Global Positioning System (GPS) Approach Procedures pilots may encounter in the National Airspace System (NAS). Generic procedures are included to illustrate the sequence of pilot actions that are required to accomplish the respective approaches.

2. A GPS OVERLAY APPROACH WITH "OR GPS" IN THE TITLE OF THE APPROACH AND NO PUBLISHED FINAL APPROACH FIX (FAF). Roanoke Rapids, North Carolina, NDB Or GPS Runway 5 (Halifax County Airport).

a. After selecting the airport and approach information as outlined in the FAA Approved Flight Manual or Flight Manual Supplement, the waypoints will be automatically presented in the proper order to fly the approach. Pilots must arm (enable) approach mode prior to the initial approach fix (IAF). This approach is considered a Phase III GPS Approach Overlay since "or GPS" appears in the title. The feeder routes from the Lawrenceville VORTAC, GUMBE Intersection, Tar River VORTAC, and DUFFI Intersection are outside the IAF. These routes are not required in the approach procedure sequence of waypoints.

Note: Some manufacturers may include feeder route information.

b. Notice that this approach does not have an final approach fix (FAF). For the final sensitivity reduction to take place however (a requirement for a GPS overlay approach), an FAF waypoint must be established. For this approach, the database and GPS display includes a "sensor FAF", which is located at the default distance of 4 NM to the missed approach point (MAP) for Runway 05. It is identified in the database by an ARINC identifier such as "FF05" (Final Approach Fix for Runway 05), but may not appear on the approach chart.

c. At the IAF (RZZ), the GPS equipment automatically sequences to the next waypoint, in this case the sensor FAF (FF05). After passing the IAF and prior to reaching the sensor FAF, the receiver is put on hold either by the pilot or automatically by the equipment depending on the manufacturer. TO-FROM navigation and an along track distance are provided in relation to the active waypoint, which in this case, is still the FAF. The procedure turn should be completed beyond the sensor FAF to ensure that the waypoint sequencing is properly achieved and that the receiver sensitivity is correctly activated. The procedure turn also should be completed within the protected airspace for the approach. In this case, within 10 NM from RAPIDS.

d. On the outbound leg of the procedure turn, set the final approach course (058°) on the OBS. When the inbound course is intercepted, the receiver is returned to automatic sequencing either by the pilot or automatically by the equipment depending on the manufacturer. TO-TO navigation and an along track distance are provided to the sensor FAF (FF05). At 2 NM from the sensor FAF, the display sensitivity begins to transition to .3 NM either side of centerline. At the sensor FAF, the GPS equipment automatically sequences to the MAP waypoint (RZZ) with an along track distance provided to the MAP.

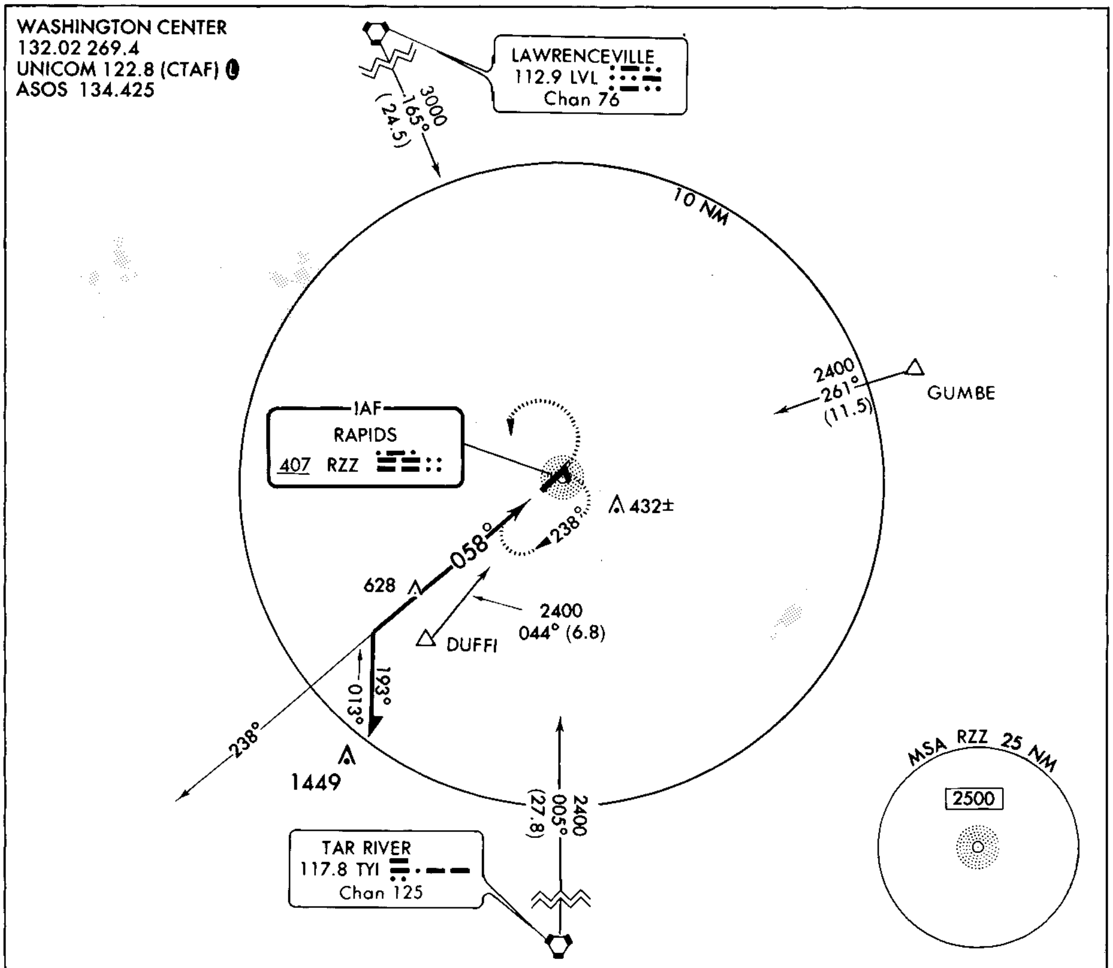
e. At the MAP, the GPS equipment must be manually sequenced to the next active waypoint. Once selected, the navigation equipment will display the missed approach holding point (RZZ). Display sensitivity full scale deflection changes to one nautical mile. The missed approach procedure is flown as depicted on the chart using normal piloting techniques; in this case, a climbing left turn to 2,400 feet and entry into a holding pattern at the RZZ waypoint. DIRECT-TO navigation is used to RZZ. After passing RZZ and while entering missed approach holding, the receiver is put on “hold” for the missed approach holding pattern.

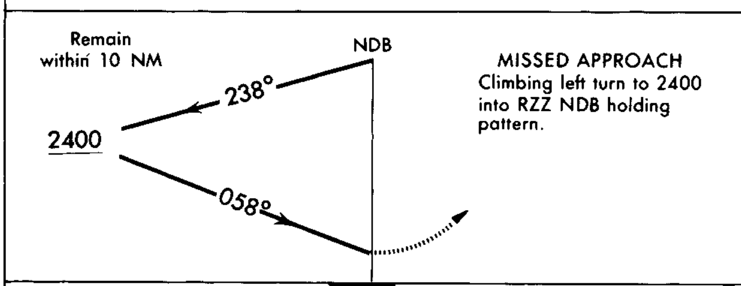
Amdt 3A 98197

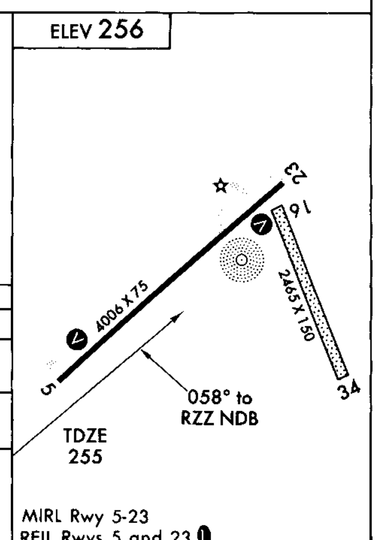
NDB or GPS RWY 5

AL-6379 (FAA)

ROANOKE RAPIDS/HALIFAX COUNTY (RZZ)
ROANOKE RAPIDS, NORTH CAROLINA







CATEGORY	A	B	C	D
S-5	980-1 725 (800-1)		980-2 725 (800-2)	980-2¼ 725 (800-2¼)
CIRCLING	980-1 724 (800-1)		980-2 724 (800-2)	980-2¼ 724 (800-2¼)

△ NA

Knots	60	90	120	150	180
Min:Sec					

NDB or GPS RWY 5

Amdt 3A 98197

36°26'N – 77°43'W

ROANOKE RAPIDS, NORTH CAROLINA
ROANOKE RAPIDS/HALIFAX COUNTY (RZZ)

3. A GPS OVERLAY APPROACH WITHOUT "OR GPS" IN THE TITLE OF THE APPROACH, WITH TWO IAF WAYPOINTS AND A "ROUTED" MISSED APPROACH: Providence, Rhode Island, VOR Runway 5 (Green State Airport).

a. After selecting the airport and approach information as outlined in the FAA Approved Flight Manual or Flight Manual Supplement, the waypoints will be automatically presented in the proper order to fly the approach. Pilots must arm (enable) approach mode prior to the IAF. Since the words "or GPS" are not included in the title of the published approach procedure chart, it may be considered a Phase II GPS Overlay Approach procedure. This chart includes the database identifiers and waypoints for the GPS Overlay Approach.

b. This approach can be initiated from one of two Initial Approach Fix waypoints: LAFAY or RENCH. The waypoint sequence if the approach is started from LAFAY is LAFAY (IAF), the turn point in the initial segment (identified by the database code PVD17), RENCH (FAF), Providence VOR (MAP), and FOSTY (MAHP). The first portion of the route is flown to a turn point waypoint. Course guidance and an along track distance is provided to the turn waypoint (PVD17) to intercept the 045° inbound course to RENCH. After passing PVD17 and intercepting the inbound course, the along track distance to RENCH can be used to determine the distance remaining to the FAF.

c. If the approach is initiated from over RENCH, the waypoint sequence is RENCH (IAF/FAF), Providence VOR (MAP), and FOSTY (MAHP). The LOM serves as the IAF and the FAF. Prior to passing RENCH IAF outbound, the GPS receiver is put on hold to fly the course reversal. Depending on the manufacturer, this may be a pilot action or done automatically by the equipment. The course reversal is flown as charted with TO-FROM navigation provided in relation to the active waypoint, which in this case, is RENCH FAF. Once established on the inbound course, the receiver should be returned to automatic waypoint sequencing (TO-TO navigation). Depending on the manufacturer, this may be a pilot action or done automatically by the equipment. An along track distance is provided to RENCH FAF. At 2 NM from RENCH FAF, the display and RAIM sensitivity transitions to 0.3 NM.

d. At the FAF, the waypoint automatically sequences to the MAP. An along track distance is provided to the MAP waypoint (PVD). Since the stepdown fix (D2.5) is not an FAA named fix, it is not included in the waypoint presentation; however, the point can be identified by an along track distance to PVD. When the ATD is 2.5 NM to the MAP, the fix is identified. Note that on some approaches this distance may be different from the DME distance depicted in the profile view. In such cases, the along track distance at the bottom of the profile view can be used to monitor the distance readout.

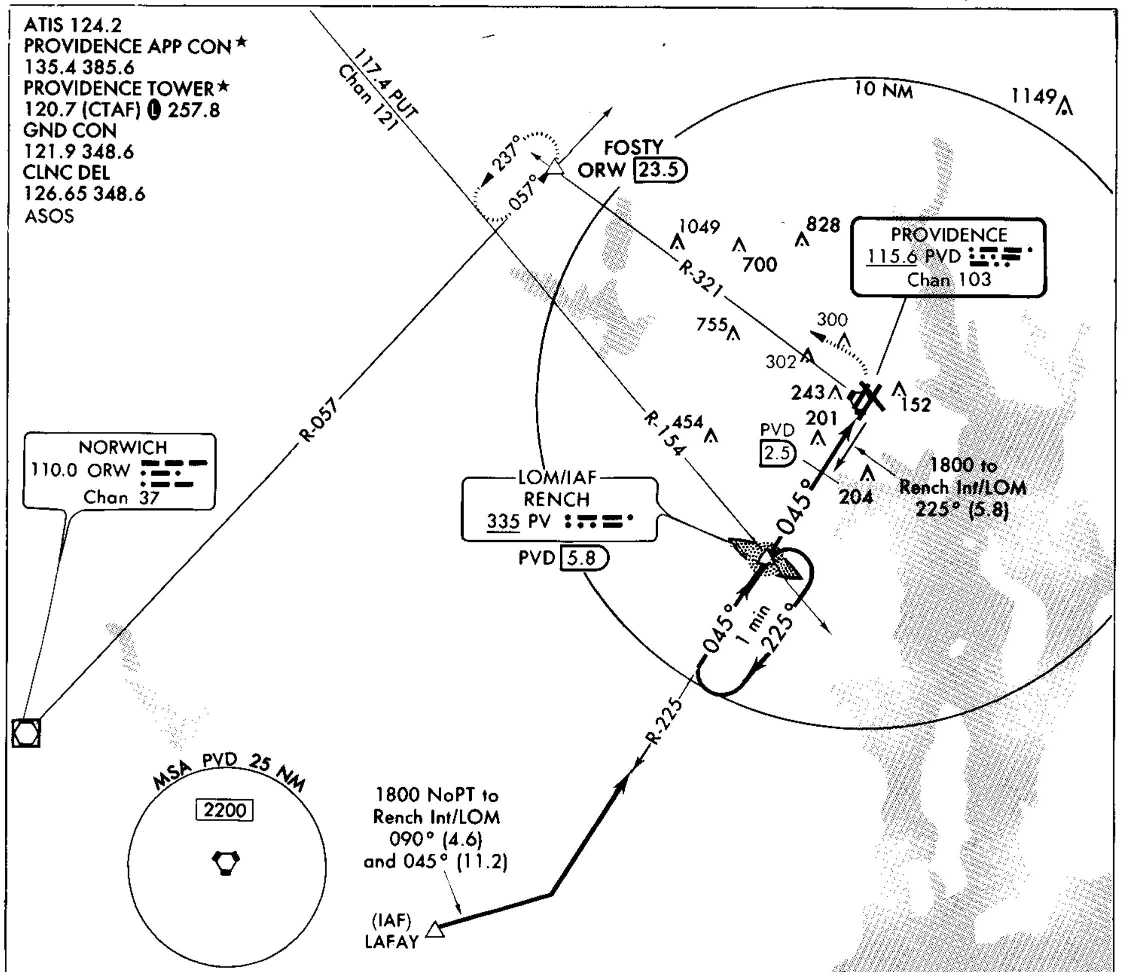
e. At the MAP waypoint, the receiver automatically changes to manual operation and the pilot must manually sequence to the next active waypoint. Once complete, display sensitivity changes to full scale deflection of one nautical mile, and the missed approach holding point is displayed as the next waypoint. The first part of the missed approach procedure is flown as depicted on the chart: climbing left turn to 2,500 feet. The pilot must manually set the 321° course, since the receiver will set the direct course from where the receiver was manually sequenced to the FOSTY intersection. Normal piloting techniques are used to intercept a 321° course (a TO-TO bearing of 321°) to FOSTY.

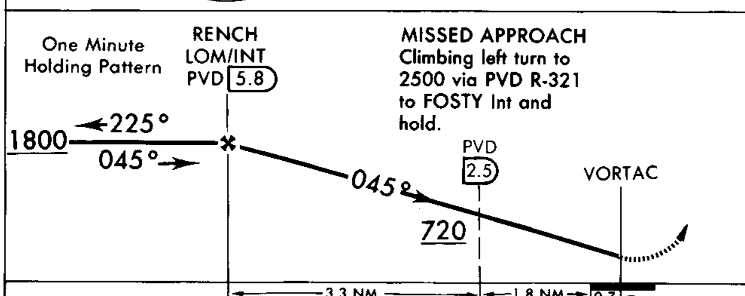
Amdt 13A 98337

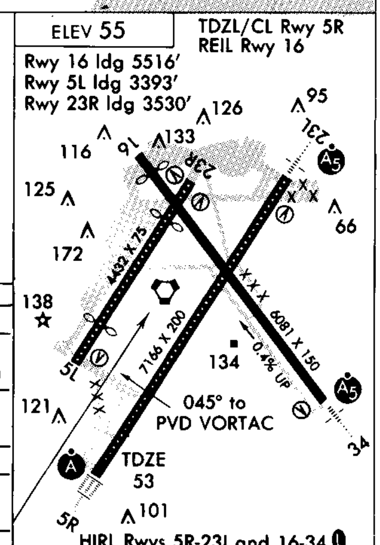
VOR RWY 5R

AL-333 (FAA)

PROVIDENCE/THEODORE FRANCIS GREEN STATE (PVD)
PROVIDENCE, RHODE ISLAND







CATEGORY	A	B	C	D
S-5R	720/24 667 (700-½)		720/60 667 (700-1¼)	720-1½ 667 (700-1½)
CIRCLING	720-1 665 (700-1)		720-1¾ 665 (700-1¾)	720-2 665 (700-2)
DME MINIMUMS				
S-5R	540/24 487 (500-½)		540/40 487 (500-¾)	540/50 487 (500-1)
CIRCLING	560-1 505 (600-1)		580-1½ 525 (600-1½)	620-2 565 (600-2)

Knots	60	90	120	150	180
Min:Sec					

VOR RWY 5R

Amdt 13A 98337

41°43' N - 71°26' W

PROVIDENCE, RHODE ISLAND
PROVIDENCE/THEODORE FRANCIS GREEN STATE (PVD)

4. A GPS "OVERLAY" APPROACH WITH AN ARC: Lake Charles, Louisiana, VOR DME-B (Lake Charles Regional Airport).

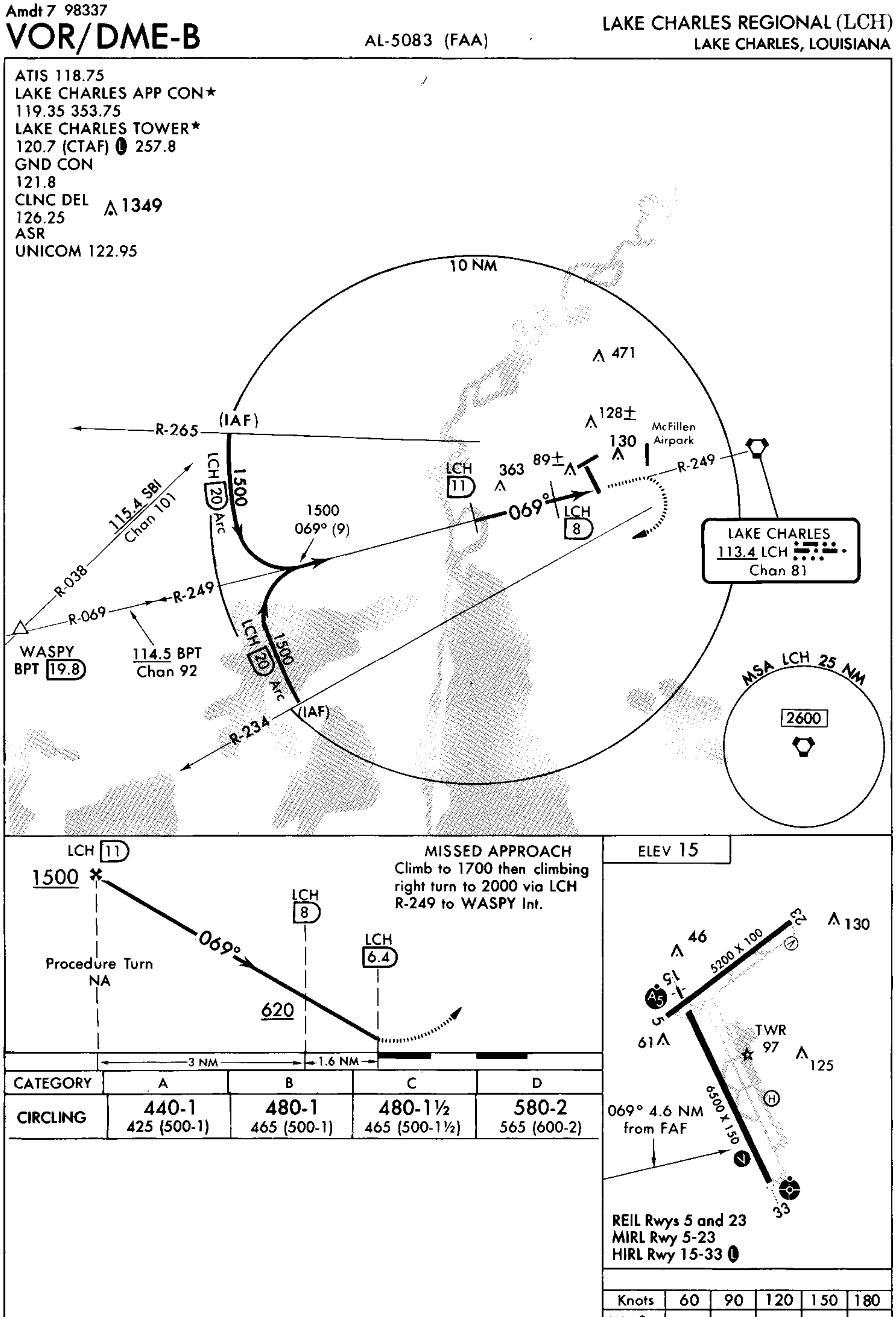
a. After selecting the airport and approach information as outlined in the FAA Approved Flight Manual or Flight Manual Supplement, the waypoints will be automatically presented in the proper order to fly the approach. Pilots must arm (enable) approach mode prior to the IAF. This example represents a Phase II GPS Overlay Approach.

b. This approach can be initiated from one of two Initial Approach Fix waypoints. These IAF waypoints are along the 20 NM arc at points defined by the 234 and 265 degree radials from LCH. The IAF at R-234 will likely appear in the database as D234T. D234T represents a point located on the 234 degree radial of the Lake Charles VORTAC at 20 NM. The letter T is the twentieth letter of the alphabet and is used to indicate a distance of 20 NM. In addition, a waypoint is coded in the database at the intersection of the arc and final approach course (CF069). The approach waypoint sequence in this case is D234T (IAF), CF069 (or D069T for intercepting the final approach course), FF069 (FAF), MA069 (MAP), and WASPY intersection. The same sequence is provided for the other arc, except that it starts at D265T. The display in the receiver and procedure for flying the arc may vary with the manufacturer. Pilots should consult the FAA Approved Flight Manual, or Flight Manual Supplement for further details.

c. From either IAF normal piloting techniques are used to maintain the ground track of the arc en route to the waypoint located at the intersection of the arc and the final approach course (CF069). From here the GPS equipment will sequence to the FAF (FF069). At 2 NM from the FAF, the display sensitivity begins transitioning to where full scale deflection is .3 NM either side of centerline.

d. At the FAF, the waypoint automatically sequences to the MAP (MA069). An along track distance is provided to the MAP waypoint. Since the stepdown fix (D8.0) is not an FAA named fix, it is not included in the waypoint presentation; however, the point can be identified by an along track distance to MA069. When the ATD is 1.6 NM to the MAP, the fix is identified. Note that on this approach there is a difference between the DME distance depicted in the profile view and the along track distance. In such cases, the along track distance at the bottom of the profile view can be used to monitor the GPS distance readout.

e. At the MAP waypoint, the receiver automatically changes to manual operation and the pilot must sequence the receiver to the next active waypoint. Once complete, the missed approach waypoint (WASPY) is displayed as the next waypoint. The first part of the missed approach procedure is flown as depicted on the chart: Climb to 1,700 feet, then climbing right turn to 2,000 feet outbound via LCH VOR R-249 to WASPY. The pilot must manually set the 249° course to WASPY, depending on when the MAWP is sequenced. Normal piloting techniques are used to intercept the 249° course (a TO-TO bearing of 249°) to WASPY. Display sensitivity begins to change to a full scale deflection of one nautical mile either side of centerline once WASPY is sequenced.



CATEGORY	A	B	C	D
CIRCLING	440-1 425 (500-1)	480-1 465 (500-1)	480-1½ 465 (500-1½)	580-2 565 (600-2)

Knots	60	90	120	150	180
Min:Sec					

VOR/DME-B
30°08'N-93°13'W
LAKE CHARLES, LOUISIANA
LAKE CHARLES REGIONAL (LCH)
Amdt 7 98337

5. A GPS "STAND ALONE" APPROACH: Phillips, Wisconsin, GPS RWY 1 (Phillips Price County (PBH)).

a. After selecting the airport and approach information as outlined in the FAA Approved Flight Manual or Pilot's Operating handbook, the waypoints will be automatically presented in the proper order to fly the approach. Pilots must arm (enable) approach mode prior to the IAF. This stand alone GPS approach can be initiated from either Initial Approach Fix waypoint: GUGFO or ABVIC. Both of the IAFs are served by feeder routes.

b. The waypoint sequence will be the appropriate IAF, URPOW, GOFXO (FAF), RW01 (MAP) and back to URPOW for missed approach holding. After passing the appropriate IAF, course guidance (TO-TO navigation) and along track distance is provided to the IF waypoint (URPOW). URPOW is a fly by waypoint and the receiver will enunciate the turn prior to reaching URPOW. During the turn, the receiver will sequence to the FAF (GOFXO) and display the inbound course and along track distance to FAF.

c. At 2 NM prior to GOFXO the CDI display and RAIM sensitivity will begin transitioning to 0.3 NM either side of center line. The pilot should confirm that the approach mode is active prior to the FAF. AT the FAF the receiver automatically sequences to the MAP (RW01) and the along track distance will show the distance remaining to the MAP. The stepdown fix at 3 NM to RW01 will not be part of the approach waypoint sequence, and must be identified using along track distance.

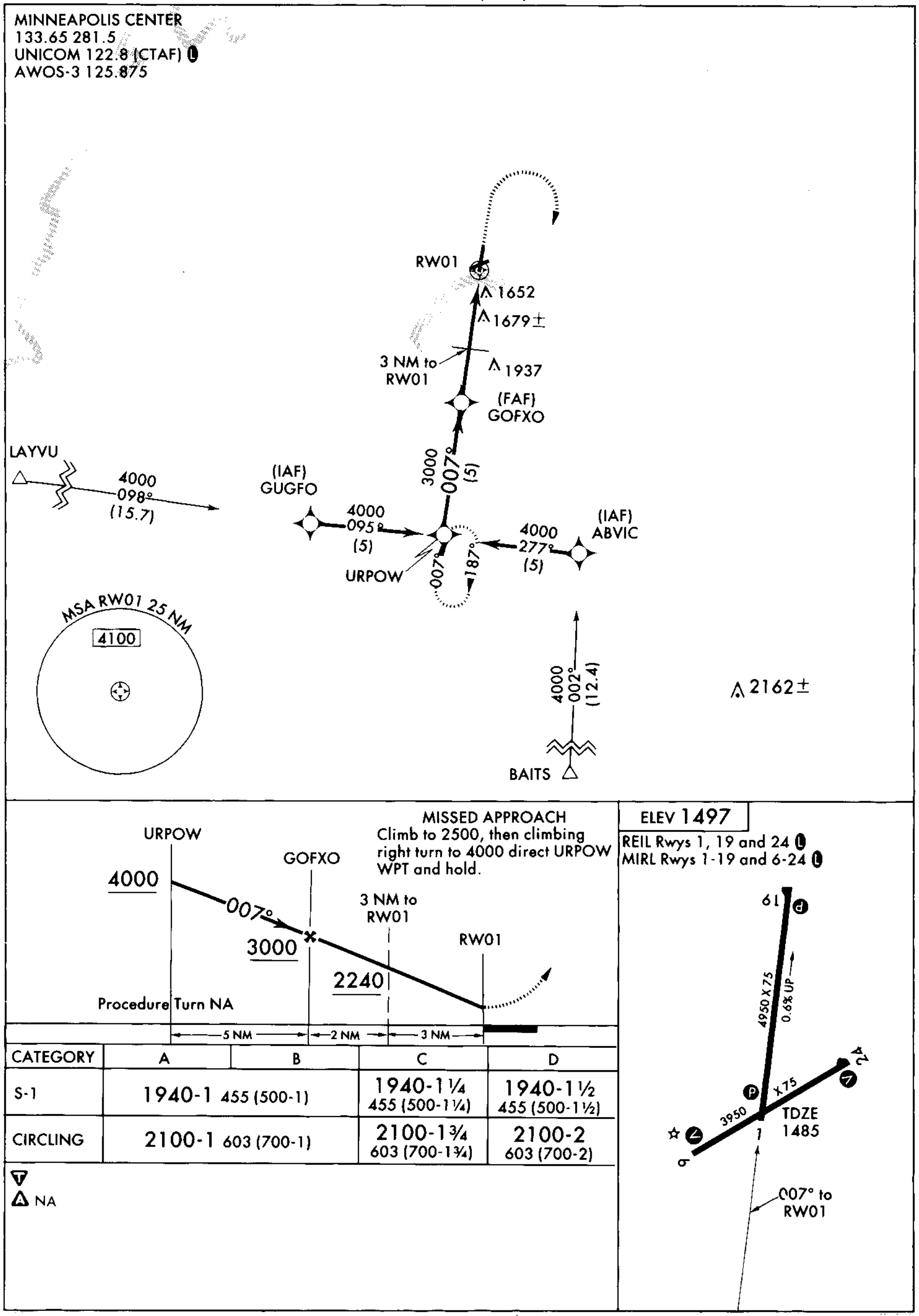
d. At the MAP (RW01) the receiver will continue to give guidance straight ahead on the inbound final approach course until the pilot manually sequences the GPS receiver to the next waypoint. In this case, the next waypoint is the missed approach holding waypoint (URPOW). However, the missed approach instructions must be complied with prior to proceeding direct to the waypoint. After climbing to 2500 feet on the extended course, continue a climbing right turn to 4000 direct URPOW waypoint. Once the aircraft is headed in the general direction of URPOW, executing the direct function will provide a direct course to URPOW.

Orig 98113

GPS RWY 1

AL-6663 (FAA)

PHILLIPS/PRICE COUNTY (PBH)
PHILLIPS, WISCONSIN



CATEGORY	A	B	C	D
S-1	1940-1 455 (500-1)		1940-1¼ 455 (500-1¼)	1940-1½ 455 (500-1½)
CIRCLING	2100-1 603 (700-1)		2100-1¾ 603 (700-1¾)	2100-2 603 (700-2)

NA

GPS RWY 1

Orig 98113

45°43'N-90°24'W

PHILLIPS, WISCONSIN
PHILLIPS/PRICE COUNTY (PBH)

6. USE OF GPS AS A SUBSTITUTE FOR ADF AND DME RECEIVERS. Provided that a facility or fix coordinates can be called up from the airborne database, an onboard GPS system may be substituted for both an ADF receiver and a DME receiver for the following operations in the U.S. National Airspace System:

a. Determining the aircraft position over a DME fix. This includes en route operations at and above 24,000 feet MSL (FL240) when using GPS as the primary navigation system.

b. Flying a DME arc.

c. Navigating to or from an NDB/compass locator.

d. Determining the aircraft position over an NDB/compass locator.

e. Determining the aircraft position over a fix made up of a crossing NDB/compass locator bearing.

f. Holding over an NDB/compass locator.

> **NOTE: An aircraft is not authorized to fly any IFR approach using GPS unless that instrument approach procedure is retrievable from the navigation database. Approach procedures that are omitted from the database can not be legally flown using GPS navigation equipment.**
> **These operations are authorized for GPS avionics approved for IFR, including multi-sensor systems with GPS a sensor. This equipment must be properly installed and meet the provisions of the applicable FAA approved Aircraft Flight Manual (AFM), Flight Manual Supplement, or Pilot Operations Manual. The required integrity for these operations is provided by Receiver Autonomous Integrity Monitoring (RAIM), or an equivalent method. For air carrier operations, operations specification approval is required to use GPS. Waypoints to be used for these operations must be retrieved from the GPS airborne database. The database must be current. If the required positions can not be retrieved from the airborne database the substitution of GPS for ADF and DME is not authorized.**
> **The GPS system must be operated within the guidelines contained in the AFM, Flight Manual Supplement or Pilot Operations Manual.**

7. THE REQUIREMENTS TO USE GPS AS A SUBSTITUTE FOR AN ADF AND DME ARE:

a. CDI Sensitivity. The Course Deviation Indicator (CDI) must be set to terminal sensitivity (normally 1 or 1 ¼ NM) when tracking GPS course guidance in the terminal area. This is to ensure that small deviations from course are displayed to the pilot in order to keep the aircraft within the smaller terminal protected areas.

b. Charting Requirements. Charting will not change to support these operations. Charted requirements for ADF and DME can be met using the GPS system, except for use as the primary instrument approach navigation source.

c. Avionics Requirements. There is no requirement for the aircraft to be equipped with an ADF or DME receiver. The ground based NDB or DME facility may be temporarily out of service during these operations.

8. POSITION DETERMINATION. The following provides general guidance which is not specific to any particular GPS system. For specific system guidance refer to the AFM, Flight Manual Supplement, Pilot Operations Manual, or contact the manufacturer of your system. To determine the aircraft position over a DME fix:

a. Verify GPS system integrity monitoring is functioning properly.

b. If the fix is identified by a five letter name which is contained in the GPS airborne database, the pilot may select either the named fix as the active GPS waypoint (WP) or the facility establishing the DME fix as the active GPS WP.

NOTE: When using a facility as the active WP, the only acceptable facility is the DME facility which is charted as the one used to establish the DME fix. If this facility is not in the GPS airborne database, it is not authorized to use a facility WP for this operation.

c. If the fix is identified by a five letter name which is <u>not</u> contained in the GPS airborne database, or if the fix is not named, the pilot must select the facility establishing the DME fix as the active GPS WP.

NOTE: An alternative, until all DME sources are in the database, is using a named DME fix as the active waypoint to identify unnamed DME fixes on the same course and from the same DME source as the active waypoint.

CAUTION: Pilots should be extremely careful to ensure that correct distance measurements are used when utilizing this interim method. It is strongly recommended that pilots review distances for DME fixing during preflight preparation.

d. If you select the named fix as your active GPS WP, you are over the fix when the GPS system indicates you are at the active WP.

e. If you select the DME providing facility as the active GPS WP, you are over the fix when the GPS distance from the active WP equals the charted DME value.

9. DME ARC. To fly a DME ARC:

a. Verify GPS system integrity monitoring is functioning properly.

b. The pilot must select, from the airborne database, the facility providing the DME arc as the active GPS WP.

> **NOTE: The only acceptable facility is the DME facility on which the arc is based. If this facility is not in the airborne database, the pilot is not authorized to perform this operation. Maintain position on the arc by reference to the GPS distance in lieu of a DME readout. Additionally, If compass locator is charted with a collocated fix of the same name, use of that fix as the active WP in place of the compass locator facility is authorized.**

10. NDB/COMPASS LOCATOR. To navigate to or from an NDB/compass locator:

a. Verify GPS system integrity monitoring is functioning properly.

b. Select terminal CDI sensitivity in accordance with the AFM, Flight Manual Supplement or Pilot Operations Manual if in the terminal area.

c. Select the NDB/COMPASS LOCATOR facility from the airborne database as the active WP.

> **NOTE: When using a facility as the active WP, the only acceptable facility is the NDB/COMPASS LOCATOR facility which is charted as the one used to establish the fix. If this facility is not in the airborne database, the pilot is not authorized to use a facility WP for this operation.**

d. Select and navigate on the appropriate course to or from the active WP.

e. Determine the aircraft position over an NDB/COMPASS LOCATOR.

f. Verify GPS system integrity monitoring is functioning properly.

g. Select the NDB/COMPASS LOCATOR facility from the airborne database as the active WP.

NOTE: When using a facility as the active WP, the only acceptable facility is the NDB/COMPASS LOCATOR facility which is charted. If this facility is not in the airborne database, the pilot is not authorized to use a facility WP for this operation.

h. The aircraft is over the NDB/COMPASS LOCATOR when the GPS system indicates you are at the active WP.

11. NDB/COMPASS LOCATOR BEARING FIX. To determine the aircraft position over a fix made up of a crossing NDB/COMPASS LOCATOR bearing:

a. Verify GPS system integrity monitoring is functioning properly.

b. A fix made up by a crossing NDB/COMPASS LOCATOR bearing will be identified by a five letter fix name. The pilot may select either the named fix or the NDB/COMPASS LOCATOR facility providing the crossing bearing to establish the fix as the active GPS WP.

NOTE: When using a facility as the active WP, the only acceptable facility is the NDB/COMPASS LOCATOR facility which is charted as the one used to establish the fix. If this facility is not in the airborne database, the pilot is not authorized to use a facility WP for this operation.

c. If the pilot selects the named fix as your active GPS WP, the aircraft is over the fix when the GPS system indicates the named WP as the pilot flies the prescribed track from the non-GPS navigation source.

d. If you select the NDB/COMPASS LOCATOR facility as the active GPS WP, you are over the fix when the GPS bearing to the active WP is the same as the charted NDB/COMPASS LOCATOR bearing for the fix as you fly the prescribed track from the non-GPS navigation source.

12. HOLDING OVER AN NDB/COMPASS LOCATOR FIX: To hold over an NDB/Compass Locator:

a. Verify GPS system integrity monitoring is functioning properly.

b. Select terminal CDI sensitivity in accordance with the AFM, Flight Manual Supplement, or Pilot Operations Manual if in the terminal area.

c. Select the NDB/COMPASS LOCATOR facility from the airborne database as the active WP.

NOTE: When using a facility as the active WP, the only acceptable facility is the NDB/COMPASS LOCATOR facility which is charted. If

this facility is not in the aircraft airborne database, the pilot is are not authorized to use a facility WP for this operation.

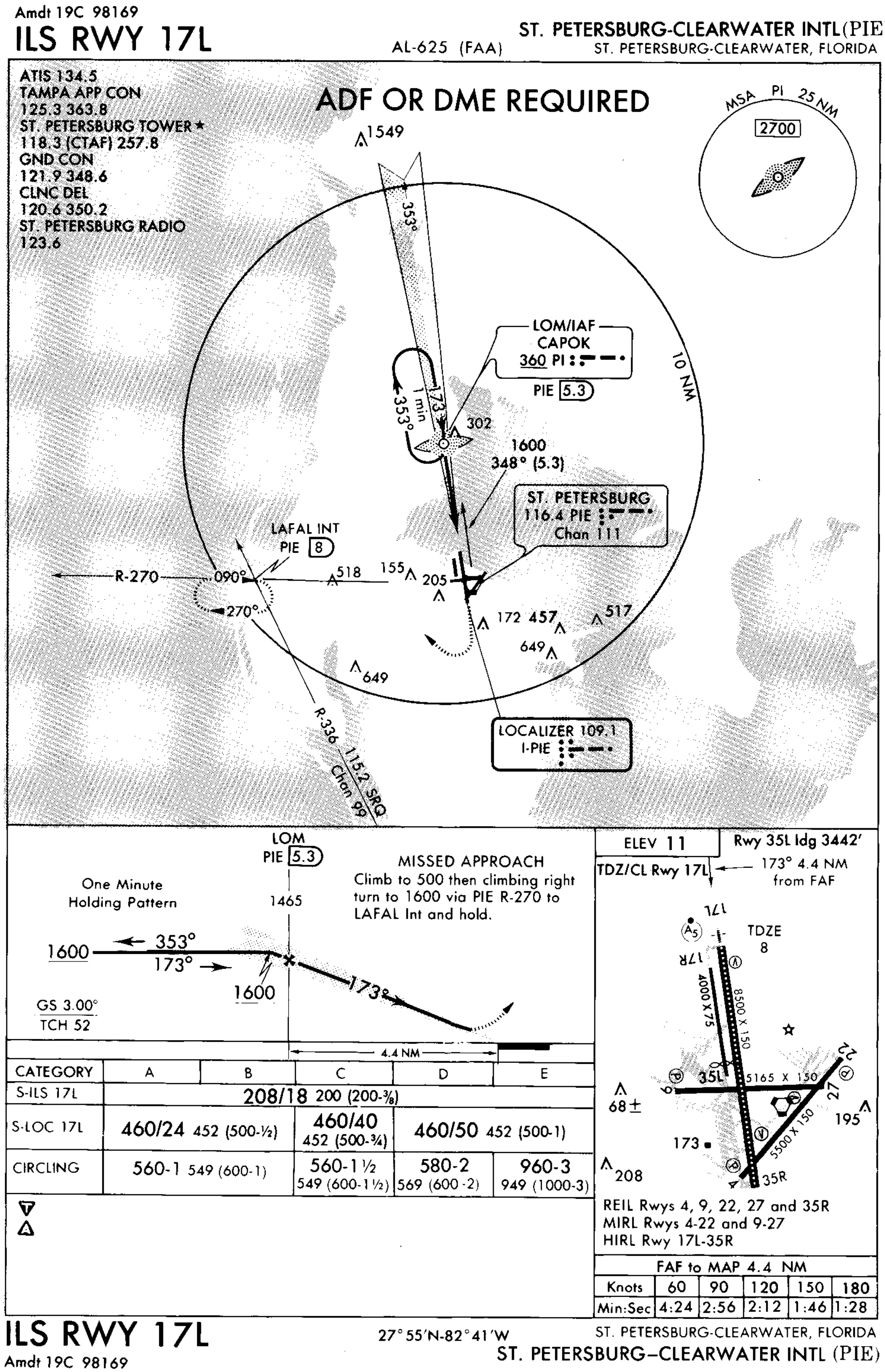
d. Select non-sequencing (e.g. “HOLD” or “OBS”) mode and the appropriate course in accordance with the AFM, Flight Manual Supplement, or Pilot Operations Manual.

e. Hold using the GPS system in accordance with the AFM, Flight Manual Supplement, or Pilot Operations Manual.

13. OTHER CONSIDERATIONS: Many GPS receivers can drive an ADF-type bearing pointer. Such an installation will provide the pilot with an enhanced level of situational awareness by providing GPS navigation information while the CDI is set to VOR or ILS. The GPS receiver may be installed so that when an ILS frequency is tuned the navigation display defaults to the VOR/ILS mode, preempting the GPS mode. However, if the receiver installation requires a manual selection from GPS to ILS it allows for the ILS to be tuned and identified while navigating on the GPS. Additionally, this prevents the navigation display from automatically switching back to GPS when a VOR frequency is selected. If an automatic switching from the VOR/ILS mode to GPS mode is caused by selecting a VOR frequency, the change may go unnoticed and could result in erroneous navigation and departing obstruction protected airspace. GPS is a supplemental navigation system in part due to availability.

14. TWO GPS APPROACHES IMPLEMENTING USE OF GPS IN LIEU OF ADF AND DME.

a. St. Petersburg-Clearwater, Florida, ILS RWY 17l (St. Petersburg-Clearwater Intl.). To fly this procedure without an ADF or DME, plan on using GPS to navigate to CAPOK and to identify LAFAL, the missed approach clearance limit. Prior to exiting the airway set up the waypoints for the compass locator CAPOK (PI) then the fix LAFAL. Exit the airway on the 348° course out of St. Petersburg VORTAC toward CAPOK. Once established outbound, switch the navigation display to GPS, in the non-sequencing mode, and fly the 348° course to CAPOK. Over CAPOK start the clock and enter the holding pattern. Outbound in holding or when cleared for the approach, set the navigation display to VOR/ILS, tune and identify I-PIE on 109.1, and select the inbound course, 173°, in the OBS. Also advance LAFAL as the active WP in the GPS, ensure GPS is in the non-sequencing mode. At one minute turn and intercept the localizer inbound. Over the outer marker (FAF) start the clock for final approach timing (localizer only). At the DH or missed approach point with no runway environment in sight, perform missed approach procedures and climb straight ahead to 500 feet MSL. After aircraft clean up, tune and identify PIE VORTAC, 116.4, and select course 270° with the OBS. On reaching 500 feet turn right and intercept the PIE 270° course outbound. The GPS distance now gives distance to LAFAL, and when over the GPS WP you are at LAFAL. Enter holding, and hold on the PIE 270° radial (090° inbound course), identifying LAFAL by reference to the GPS. An alternative way to identify LAFAL: use PIE VORTAC as the active WP and when on the 270 radial, with PIE VORTAC tuned up and selected to the navigation display, you are at LAFAL when the GPS distance reads 8 NM.



CATEGORY	A	B	C	D	E
S-ILS 17L	208/18 200 (200-⅝)				
S-LOC 17L	460/24 452 (500-½)		460/40 452 (500-¾)	460/50 452 (500-1)	
CIRCLING	560-1 549 (600-1)		560-1½ 549 (600-1½)	580-2 569 (600-2)	960-3 949 (1000-3)

FAF to MAP 4.4 NM					
Knots	60	90	120	150	180
Min:Sec	4:24	2:56	2:12	1:46	1:28

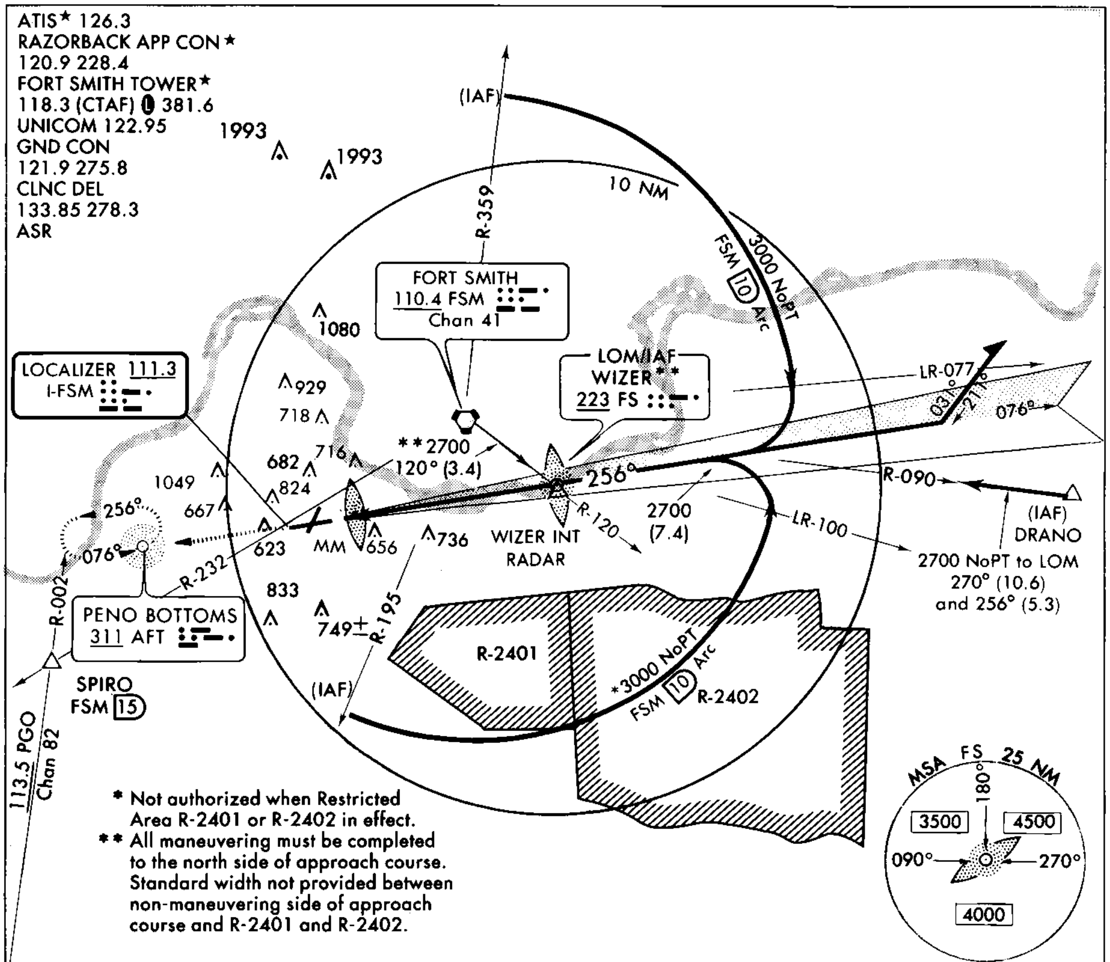
b. Fort Smith, Arkansas, ILS RWY 25 (Fort Smith Regional). Arriving from the northeast on V-289, use GPS to fly the initial segment arc and to hold at Peno Bottoms, the missed approach clearance limit. Add the Fort Smith VORTAC to the waypoint list followed by Peno Bottoms NDB. Assuming you are cleared for the approach as you proceed southwest on the airway navigating to Fort Smith VORTAC, have Fort Smith VORTAC as the active WP. Monitor the GPS distance, and turn left to intercept the arc when it reads 10.5 NM. As you fly the arc, monitor the bearing from Fort Smith. When you reach the 077° lead radial, tune and identify I-FSM, select 256° on the OBS, ensure the navigation display is set to VOR/ILS, and intercept the localizer. Advance the GPS to Peno Bottoms and set it to non-sequencing mode. Fly the ILS normally, identifying the FAF by the outer marker. At the DH without the runway environment in sight, perform missed approach procedures and climb straight ahead. Change the navigation display to GPS, select "DIRECT" on the GPS receiver and fly to the Peno Bottoms WP. Approaching Peno Bottoms, ensure the GPS is set in the non-sequencing mode. At Peno Bottoms turn to enter holding and, while outbound,
set 076° for the inbound course. Hold.

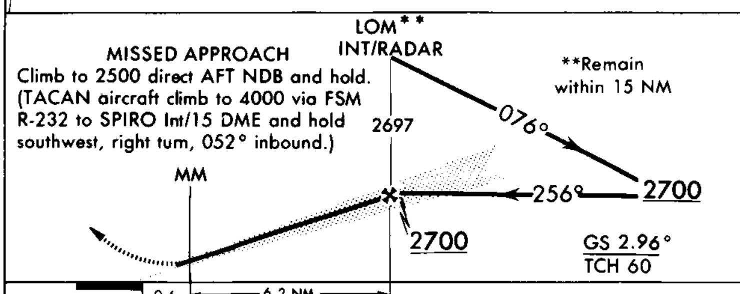
Amdt 20 97310

ILS RWY 25

AL-631 (FAA)

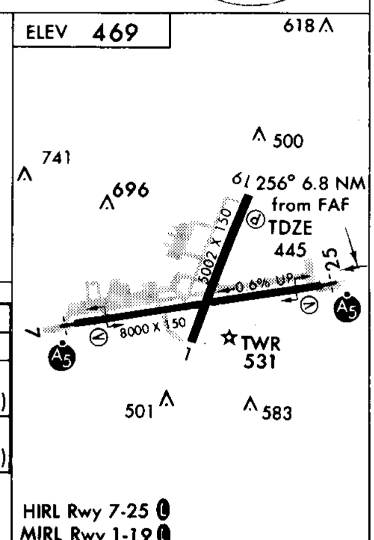
FORT SMITH REGIONAL (FSM)
FORT SMITH, ARKANSAS





CATEGORY	A	B	C	D	E
S-ILS 25	645-½ 200 (200-½)				
S-LOC 25	940-½ 495 (500-½)		940-¾ 495 (500-¾)	940-1 495 (500-1)	940-1¼ 495 (500-1¼)
CIRCLING	1140-1 671 (700-1)		1140-2 671 (700-2)	1140-2¼ 671 (700-2¼)	1140-2½ 671 (700-2½)

Circling not authorized NW of Rwys 7 and 19 for Cat. E.



FAF to MAP 6.8 NM					
Knots	60	90	120	150	180
Min:Sec	6:48	4:32	3:24	2:43	2:16

ILS RWY 25

Amdt 20 97310

35°20'N-94°22'W

FORT SMITH, ARKANSAS
FORT SMITH REGIONAL (FSM)

APPENDIX 4 - OPERATOR SELECTED PRACTICES

1. THE GPS APPROVAL PROCESS.

a. 14 CFR Part 91 Operators. Section 91.703 addresses the operation of aircraft of U.S. civil registry operated outside the United States. Section 91.703(a)(1) states, in pertinent part, that each person operating an aircraft of U.S. civil registry shall, when operating over the high seas, comply with Annex 2 (Rules of the Air) to the Convention on International Aviation. Additionally, Section 91.705, **Operations within the North Atlantic Minimum Navigation Performance Specifications (MNPS) Airspace,** requires that, unless the Administrator authorizes a deviation, no person may operate an aircraft of U.S. civil registry in the North Atlantic airspace designated as MNPS airspace unless the aircraft has approved navigation performance capability and the operator is authorized by the Administrator to perform such operations.

(1) General Aviation (GA) operators are required to obtain an Letter of Authorization (LOA) for operations in special qualifications airspace. For the purpose of this AC, special qualifications airspace is where navigation performance standards are governed by international agreements, separation minimums are reduced, and the standards of navigation performance accuracy is strictly enforced. In particular this airspace is MNPS airspace and the North Atlantic (NAT) region where lateral separation is 60 NM. There is no requirement for a GA operator to obtain permission from the U.S. Government (in the form of a LOA) for oceanic operations outside special qualifications airspace.

(2) Operators initiate the approval process by letter of application to the appropriate Flight Standards District Office for operational authorization to use the GPS system(s) or GPS-based multisensor navigation system(s) for the intended operation. An FAA Aviation Safety Inspector (ASI) (Operations) will review the applicant's navigation procedures, training, and procedures for use of the FDE prediction program and other operational issues. An FAA ASI (Avionics) will review the applicants' airworthiness approval and maintenance procedures. For specifics on this entire approval process, refer to Chapter 222, FAA Order 8700.1, General Aviation Operations Inspector's Handbook, and AC 91-70, Oceanic Operations.

(3) All operators are encouraged to obtain training in the operation of their particular navigation unit and in operations outside the U.S. Additionally, all aircraft (including U.S. civil registered aircraft) departing from Canadian airspace into international airspace require approval from the Canadian government prior to departure.

b. 14 CFR Part 125 Operators: All GPS operations conducted by operators under part 125 must be authorized in the operators Operations Specifications. Any questions or comments concerning operational approval of GPS for part 125 operators should be directed to AFS-820 at (202) 267-8194.

c. 14 CFR Parts 121 and 135 Operators. All GPS operations conducted by U.S. air carriers and commercial operators under part 121 or 135 must be approved by the Certificate Holding District

Office (CHDO) in accordance with FAA guidance and procedures. Some specific areas requiring approval are:

(1) GPS Pilot Training Programs

(2) GPS Dispatch Procedures

(3) GPS Avionics Installation and Continuing Maintenance Procedures

(4) Operations Specifications Approvals for GPS Operations

d. Comments. Any questions or comments concerning operational approval of GPS for air carrier operators should be directed to AFS-220 at (202) 267-7579.

2. FAA APPROVAL FOR USE OF GPS FOR ALL OPERATORS.

a. GPS Equipment Approval. The equipment must be approved by the FAA Aircraft Certification Office (ACO) in accordance with AC 20-138, Airworthiness Approval of Global Positioning System (GPS) Navigation Equipment For Use As A VFR And IFR Supplemental Navigation System; or AC 20-130A, Airworthiness Approval of Navigation or Flight Management Systems Integrating Multiple Navigation Sensors; and (if required) Notice (N) 8110.60, GPS as a Primary Means of Navigation for Oceanic/Remote Operations.

b. Installation. The applicant must obtain initial installation approval of GPS equipment for primary means use on a specific make and model aircraft via the Type Certificate (TC) or the Supplemental Type Certificate (STC) certification process. The FAA Form 337 or forms acceptable to the Administrator for those operators with an acceptable engineering organization will be used for follow-on installation of the same GPS equipment provided the data developed for the initial certification is used.

c. Aircraft Flight Manual Supplement (AFMS). Once the installation has been approved, the AFMS must be updated to state: "The (type)_______ GPS equipment as installed has been found to comply with the requirements for GPS primary means of Class II navigation in oceanic and remote airspace, when used in conjunction with the (type)________ prediction program. This does not constitute operational approval."

d. Training and Manuals: Crew training is required to ensure crews are familiar with navigation equipment operations, data base updating procedures, pre-departure procedures, standard en route procedures, and contingency procedures.

e. Crew Qualification: The required flight crew must have received training in the use of GPS.

3. FAA APPROVAL FOR USE OF GPS FOR OPERATORS INTENDING TO CONDUCT OCEANIC OPERATIONS: Operators must ensure that the following policies and procedures are incorporated into pilot and, where appropriate, dispatcher training/qualification programs and manuals:

a. FDE Availability Prediction Program. All operators conducting GPS primary means of Class II navigation in oceanic/remote areas under parts 91, 121, 125 and 135 must utilize an FAA-approved FDE prediction program for the installed GPS equipment that is capable of predicting, prior to departure, the maximum outage duration of the loss of fault exclusion, the loss of fault detection, and the loss of navigation function for flight on a specified route. The "specified route of flight" is defined by a series of waypoints (to include the route to any required alternates) with the time specified by a velocity or series of velocities. Since specific ground speeds may not be maintained, the pre-departure prediction must be performed for the range of expected ground speeds. This FDE prediction program must use the same FDE algorithm that is employed by the installed GPS equipment and must be developed using an acceptable software development methodology (e.g., RTCA/DO-178B). The FDE prediction program must provide the capability to designate manually satellites that are scheduled to be unavailable in order to perform the prediction accurately. The FDE prediction program will be evaluated as part of the navigation system's installation approval. The requirements for the FDE prediction algorithm can be found in this AC.

b. Operational Control Restrictions. Operators must observe the following operational control restrictions:

(1) Any predicted satellite outages that result in the inability of GPS equipment to provide a navigation solution on the specified route of flight requires that the flight be canceled, delayed, or re-routed.

(2) If the fault exclusion capability outage (exclusion of a malfunctioning satellite) exceeds the acceptable duration on the specific route of flight, the flight must be canceled, delayed, or re-routed.

c. Determination of the Capability to Navigate. Prior to departure, the operator must use the FDE prediction program to demonstrate that there are no outages in the capability to navigate on the specified route of flight (the FDE prediction program determines whether the GPS constellation is robust enough to provide a navigation solution for the specified route of flight).

d. Determination of Availability of Exclusion. Once navigation function is assured (the equipment can navigate on the specified route of flight), the operator must use the FDE prediction program to demonstrate that the maximum outage of the capability of the equipment to provide fault exclusion for the specified route of flight does not exceed the acceptable duration (fault exclusion is the ability to exclude a failed satellite from the navigation solution). The acceptable duration (in minutes) is equal to the time it would take to exit the protected airspace (one-half the lateral separation minimum) assuming a 35 NM per hour cross-track navigation system error growth rate when starting from the center of the route. For example, a 60-nautical mile lateral separation minimum yields 51 minutes acceptable duration (30 NM divided by 35 NM per hour). If the fault exclusion outage exceeds the acceptable duration, then the flight must be canceled, delayed, or re-routed.

NOTE: LATERAL SEPARATION MINIMUMS OR ROUTE WIDTHS MAY BE FOUND IN ICAO REGIONAL

SUPPLEMENTARY PROCEDURES, DOCUMENT 7030; THE OCEANIC AIR TRAFFIC CONTROL HANDBOOK, FAA ORDER 7110.83; OR THE AERONAUTICAL INFORMATION PUBLICATION(S) (AIP) OF THE STATE(S) PROVIDING AIR TRAFFIC SERVICES ALONG THE PLANNED ROUTE. THE OPERATOR IS ULTIMATELY RESPONSIBLE FOR ENSURING THAT THE APPROPRIATE LATERAL SEPARATION MINIMUMS ARE USED IN THE FDE PREDICTION. SOME EXAMPLES ARE:
60 NM SEPARATION IN NAT MNPS AIRSPACE
50 NM ON PACIFIC RNP-10 ROUTES
90 NM FOR U. S. DOMESTIC OFFSHORE OPERATIONS
100 NM AND 120 NM IN MANY OTHER OCEANIC AREAS WORLDWIDE

e. En route Procedures. Operators must ensure that the following policies and procedures are incorporated into pilot and, where appropriate, dispatcher training/qualification programs and manuals:

(1) Degraded Navigation Capability. If the GPS displays a "loss of navigation function" alert, the pilot should immediately begin using dead reckoning procedures until GPS navigation is regained. The pilot will report degraded navigation capability to Air Traffic Control (ATC) in accordance with section 91.187. Additionally, flight crew members operating under part 121 will notify the appropriate dispatch or flight following facility of any degraded navigation capability in accordance with the air carrier's FAA approved procedures.

(2) Satellite Fault Detection Outage. If the GPS displays an indication of a fault detection function outage (i.e., Receiver Autonomous Integrity Monitoring (RAIM) is not available), navigation integrity must be provided by comparing the GPS position with a position computed by extrapolating the last verified position with true airspeed, heading, and estimated winds. If the positions do not agree to within 10 NM, the pilot should immediately begin using dead reckoning procedures until the exclusion function or navigation integrity is regained and report degraded navigation capability to ATC in accordance with section 91.187.

(3) Fault Detection Alert. If the GPS displays a fault detection alert (failed satellite), the pilot may choose to continue to operate using the GPS-generated position if the current estimate of position uncertainty displayed on the GPS from the FDE algorithm is actively monitored. If this number exceeds 10 NM or is not available, the pilot should immediately begin using dead reckoning procedures until the failed satellite is excluded and report degraded navigation capability to ATC in accordance with section 91.187.

f. Operators Without Previous Class II Navigation Experience: If an operator is requesting approval to conduct Class II Navigation with an aircraft/GPS equipment, but has no previous experience in conducting Class II navigation, then the operator must conduct at least one validation test flight in the Class II area of navigation where it intends to operate. This flight must be conducted as a non-revenue operation with the exception that cargo may be carried.

g. Operators With Previous Class II Navigation Experience. If an operator is requesting approval to conduct Class II Navigation with an aircraft/GPS equipment combination with which it has not previously conducted Class II operations, the operator must conduct a validation test flight according to the following guidance:

(1) If the flight is conducted in a Class I navigation area to simulate operation in a Class II Navigation area, then the flight may be conducted as a revenue flight.

(2) If the flight is conducted in a Class II Navigation area, and the GPS avionics is supplemented by some other Long Range Navigation system (e.g. INS), then it may be conducted as a revenue flight.

(3) If the flight is conducted in a Class II Navigation area solely with GPS as the navigation system, then it must be conducted as a non-revenue flight with the exception that cargo may be carried.

h. Conditions of Validation Test Flights. The following conditions apply to validation test flights:

(1) At least one flight should be observed by an FAA aviation safety inspector.

(2) Dispatch procedures must be demonstrated for the Class II Navigation area(s) where operations are intended to be conducted.

(3) The flight(s) should be of adequate duration for the pilots to demonstrate knowledge of dispatch requirements, capability to navigate with the system, and to perform normal and non-normal procedures.

i. Policy Deviations. Requests to deviate from this policy should be forwarded to AFS-400 for consideration at (202) 267-3752.

APPENDIX 5 - WIDE AREA AUGMENTATION SYSTEM (WAAS)

1. GENERAL. WAAS will enhance the capability of the GPS Standard Positioning Service (SPS) to meet the accuracy (the difference between the measured position at any given time to the actual or true position), availability (the ability of a system to be used for navigation whenever it is needed by the users, and its ability to provide that service throughout a flight operation), and integrity (the ability of a system to provide timely warnings to users or to shut itself down when it should not be used for navigation) requirements critical to safety of flight.

a. In order to meet these requirements the FAA is developing the Wide Area Augmentation System or WAAS. WAAS is a safety-critical navigation system that will provide a quality of positioning information never before available to the aviation community. It is what the name implies, a geographically expansive augmentation to the basic GPS service. The WAAS improves the accuracy, integrity, and availability of the basic GPS signals. This system will allow satellite navigation to be used as the only means of navigation for en route and terminal phases of flight and instrument approaches in the U.S. National Airspace System (NAS). The wide area of coverage for this system includes the entire United States and some adjacent areas such as Canada and Mexico.

b. The WAAS is based on a network of WAAS reference stations (WRS's) that covers a very large service area. These WRS's are linked to form the WAAS network. Each of these precisely surveyed WRS's receive GPS signals and determine if any errors exist. Each WRS in the network relays the data to the wide area master station (WMS) where correction information is computed. The WMS calculates correction algorithms and assesses the integrity of the system. A correction message is prepared and uplinked to geostationary satellites (GEO's) via a ground uplink system (GUS). The message is then broadcast on the same frequency as GPS (L1, 1575.42MHz) to receivers within the broadcast coverage area of the GEO's. The GEO's also act as additional navigation satellites for the aircraft, providing additional ranging signals for position determination.

c. The WAAS will improve GPS SPS accuracy to approximately 7 meters vertically and horizontally, improve system availability through the use of GEO's, and provide important integrity information about the entire GPS constellation.

APPENDIX 6 - LOCAL AREA AUGMENTATION SYSTEM (LAAS)

1. The LAAS is intended to complement the Wide Area Augmentation System (WAAS) and function together to supply users of the U.S. National Airspace System (NAS) with seamless satellite based navigation for all phases of flight. In practical terms, this means that at locations where the WAAS is unable to meet existing navigation and landing requirements (such as availability), the LAAS will be used to fulfill those requirements. In addition, the LAAS will meet the more stringent Category II/III requirements that exist at selected locations throughout the U.S. Beyond Category III, the LAAS will provide the user with a navigation signal that can be used as an all weather surface navigation capability, enabling the potential use of LAAS as a component of a surface navigation system and an input to surface surveillance/traffic management systems.

2. Similar to the WAAS concept which incorporates the use of geostationary satellites (GEO's) to broadcast a correction message, the LAAS will broadcast its correction message via very high frequency (VHF) radio datalink from a ground-based transmitter.

3. The LAAS will yield the extremely high accuracy, availability, and integrity necessary for Category I/II/III precision approaches. It is fully expected that the end-state LAAS will provide accuracy to pinpoint an aircraft's position to within one meter or less.

4. The LAAS will provide many benefits for all users. Curved or segmented precision approach paths, impossible using the current instrument landing systems, will be possible with LAAS. Unlike current instrument landing systems (ILS, MLS), a single LAAS ground station will provide precision approach capability to all runway ends at an airfield, eliminating the need for multiple ILS/MLS installations solely for the purpose of serving multiple runways.